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USSR Report

SPACE BIOLOGY AND AEROSPACE MEDICINE

VOL 20, No 4, JULY-AUGUST 1986

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JPRS-USB-86-006

8 OCTOBER 1986

USSR REPORT

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol 20, No 4, July-August 1986

[Translation of the Russian-language bimonthly journal KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA published in Moscow by Izdatelstvo "Meditsina"]

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PUBLICATION DATA

English title	:	SPACE BIOLOGY AND AEROSPACE MEDICINE Vol 20, No 4, Jul-Aug 86
Russian title	:	KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA
Editor	:	O. G. Gazenko
Publishing house	:	Meditsina
Place of publication	:	Moscow
Date of publication	:	July-August 1986
Signed to press	:	19 June 1986
Copies	:	1470
COPYRIGHT	:	"Kosmicheskaya biologiya i aviakosmicheskaya meditsina", 1986

SURVEYS

UDC: 613.693-07:[612.843.63:612.821.2

DISTINCTIONS OF VISUAL MONITORING OF INSTRUMENT READINGS IN MANEUVERED FLIGHT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 [manuscript received 20 Apr 85) pp 4-8

[Article by I. D. Malinin and V. A. Ponomarenko]

[English abstract from source] Visual monitoring of flight parameters in a maneuvering flight simulated by a pilot trainer was investigated. Eye movements were recorded using a Japanese NAC cinecamera. It was concluded that visual monitoring and attention concentration included chained routes of predicted sequence which was determined by current events throughout the flight. The most interesting finding was that the chains of gaze switching between angular parameters of spatial position or parameters of pitch and roll flights included several components whereas the chains of gaze switching between one parameter of the angular position and one parameter of the trajectory control or between two parameters of the trajectory control included exclusively one component. Circular or closed routes of gaze switching and chained proper or open multicomponent routes were discriminated. In a complex flight the chained or circular routes between two parameters of the angular coordinates became longer. This paper describes the microstructure of gaze switching within one indicator (air horizon) and discusses important problems requiring further research.

[Text] A pilot's professional performance and, in particular, the study of mechanisms of mental control of sensorimotor acts are the basic subject of investigation in aviation psychology. For this purpose, a team of USSR physician-pilots (V. A. Popov, I. A. Kamyshov, N. A. Fedorov, V. G. Lazarev, V. G. Mylnikov, V. G. Kuznetsov, G. I. Neverov and others), headed by Prof K. K. Platonov, developed and introduced to practical aviation medicine an objective method of evaluating the pilot's visual monitoring of instrument readings by means of filming his gaze [5, 6, 9]. This method became a means of studying distribution and switching of attention for flight training methodologists [7]. The basic results of the first stage of such investigations (1950-1960) consist of the following summary facts: 1) organization of attention, i.e., the orientation of the pilot's consciousness, is determined by the nature of the flight assignment, distinctions of tactical flight characteristics of the operated aircraft and ground-based radio support of missions; 2) extent of discreteness

of visual monitoring of navigation and flight parameters can serve as an indicator of loss of spatial orientation; 3) construction of the coordinated piloting movement of controls is possible, even without direct visual monitoring, due to proprioceptive afferentation; 4) the gaze filming method can be used effectively to determine the load on pilot attention as related to the type of piloting tasks, to assess the similarity of a ground-based trainer to an actual aircraft, in assessing the pilot's work place from the standpoint of engineering psychology [2, 3, 7].

The technical refinement of the method of filming the direction of the gaze (G. V. Anisimov, A. M. Safronov, B. V. Shchadronov) in 1960-1970 rendered it one of the principal elements in engineering psychology research [1]. In those years, a new scientific school of engineering psychologists (V. V. Davydov, V. V. Lapa, B. L. Gorelov, A. N. Razumov, V. V. Polyakov, I. D. Malinin, V. A. Ponomarenko) was founded under the supervision of N. D. Zavalova, within the framework of aviation medicine.

Soviet aviation engineering psychology was the first to reveal a new content in regulatory mechanism when operating an aircraft in manual ["director"] and automatic modes. It was proven that the image of the light, rather than automated skills, plays the leading role. On the basis of studies of data processing patterns, specifications were formulated for future flight director instruments [3].

Modification of the method of filming the eyes made it possible to effect deeper studies of decision-making processes in emergency inflight situations as related to the composition, volume and type of data environment. The findings revealed that it is not so much the available information (i.e., perception process), but degree of development of effective thinking that is the prime factor for effective action in an emergency situation.

We submit here the results of investigation of visual performance of pilots throughout an instrument flight involving elements of complicated maneuvering.

The objective of this work consisted of the following: to determine the quantitative patterns of distribution of gaze fixation among different dials (indicators) within the combined navigation and flight instruments; to determine the typology of the path followed by the gaze and its psychological content; to demonstrate the dynamics of characteristics of oculomotor activity in flight, as a function of the type of flying assignment.

Methods

These studies were conducted on a modern flight simulator. The camera equipment of the Japanese firm, NAC, was used to record transfer of gaze. A record was made of take-off, altitude gain with a 30° left bank, horizontal flight, left turn with 30° bank, right turn with 30° bank, dive with 30° pitch, ascending spiral with 30° left bank, descending spiral with 30° left bank, landing approach in automatic mode. The film was interpreted manually. After transfer of the data on punchcards, they were processed on an electronic digital computer using a special program that we prepared, together with V. K. Filosofov,

programmer-engineer. A total of four first-class pilots participated in this study.

Results and Discussion

Table 1 lists summary data on distribution of pilot attention during performance of all piloting elements in the zone. They indicate the percentage of time given by pilots to each display or one of the displayed parameters (in the case of an attitude director indicator) of the flight.

Table 1. General characteristics of visual monitoring throughout performance of flight assignment (% of total time for each element of flight in the zone)

Element of flight assignment	Flight-navigation instruments and dials on which pilot fixed his gaze									
	attitude director indic.			rate-of-climb indic.	speed indicator	altimeter	navigation plan indic.	machmeter	rpm indic.	other instruments
	left bank	pitch	right bank							
Take-off	13	40	8	6	15	1	6	2	—	9
Altitude gain with left bank	33	23	—	7	7	5	5	6	7	7
Horizontal flight	7	45	—	11	6	7	15	2	6	1
Left turn with 30°bank	31	34	—	8	6	5	3	4	7	1
Right turn with 30° bank	1	44	20	8	9	3	7	—	—	8
Dive with 30° pitch	13	43	11	5	10	3	2	4	5	4
Ascending spiral with 30° right bank	—	50	22	5	3	3	2	4	7	4
Descending spiral with 30° left bank	30	38	—	10	6	3	3	4	2	4
Landing approach in automatic mode	1	27	—	7	10	6	8	9	18	14

We see from the data in Table 1 that pilots spend 50-70% of the total monitoring time on solving problems of holding the angular spatial coordinates of the aircraft on the pitch and bank axes, and the pitch indicator was the dominant point fixed with the gaze.

We were impressed by the distinct asymmetry of reading bank angles, depending on the direction of the turn or spiral. Expressly these findings, as well as the results of an investigation made during a real flight, enabled N. D. Zavalova to formulate the thesis of spatial orientation as an independent mental action effect concurrently with piloting the aircraft. During an instrument flight, situations arise where the objective of precision piloting prevails over spatial orientation, and vice versa [4].

The data in Table 1 indicate that precision flying tasks involving a single instrument lead to narrowing of pilot attention and, consequently, impoverishment of the integral image of spatial position of the aircraft.

We should dwell in particular on the following result of the investigations. It is known that the increasing difficulty of operating an aircraft is being attributed to increase in number of instruments. However, our investigations revealed that the degree of tension of perception and information-processing processes is not directly related to the number of instruments, but more to the subjective importance and probability of change in monitored parameters. This determines the individual typology of visual monitoring, which is in the form of cyclic paths.

Table 2. Basic variants and time share of cyclic paths in overall structure of distribution of pilot attention (% of total filming time)

Successive elements of flight assignment	Periodically encountered cyclic paths within one integral indicator (ADI)	Periodically encountered cyclic paths among different instruments
Take-off	Pitch → bank → pitch (14)	Pitch → speed → pitch (16) Pitch → RCI → pitch (9)
Horizontal flight	Pitch → bank → pitch (14)	Pitch → course → pitch (12) Pitch → RCI → pitch (8)
Left turn with 30° bank	Pitch → bank → pitch (18)	Pitch → RCI → pitch (14) Bank → speed → bank (4) Bank → course → bank (3)
Dive at 30° pitch	Pitch → bank → pitch (24)	Pitch → RCI → pitch (5) Pitch → speed → pitch (5) Pitch → course → pitch (4)
Ascending spiral with 30° bank	Pitch → bank → pitch (51)	Pitch → speed → pitch (13) Pitch → RCI → pitch (10) Pitch → course → pitch (4)
Landing approach in automatic mode	None	Course → RCI → course (4) Pitch → rpm → pitch (3) Altimeter → speed → altimeter (1)

Key: RCI) rate-of-climb indicator ADI) attitude director indicator

We use the term, cyclic paths of gaze movement, to refer to distribution of attention at some time segment exclusively among two instruments or indicators. These paths may have one, two or many links.

The results are listed in Table 2.

According to the data in Table 2, the types of cyclic paths are determined by the nature of the piloting task and they differ in time spent to implement them.

Table 2 shows that a paired combination of two parameters of holding the flight mode--bank and pitch angles--are the predominant variant of cyclic path.

The obtained data enable us to expound the hypothesis that, in a maneuvering flight, the pilot not only checks instrument readings with the expected values [11, 12], but also interrogates instruments for ongoing solutions to mathematical operations in his mind, and binary quantization of flow of information is the main interrogation strategy or (which is the same thing) paired interrogation of functionally interrelated indicators for a specific period of time, with precise quantitative measurement of each of two controlled parameters. This strategy of exploratory-orienting behavior in the pilot suggests that the pilot does not

read information in fragments from individual instruments, but at least from two instruments or indicators, mentally integrating them and comparing readings.

The structure of distribution of the pilot's visual attention is an objective indicator of aerodynamic characteristics of the aircraft, its stability and maneuverability. In the case of holding to the precision of maneuvering parameters, the next step in the interrogation does not always depend on the preceding event, but is determined by the present signal. Actually, herein lies one of the causes of disturbances in spatial perceptions with retention of of automated motor acts. We interpret this phenomenon from the standpoint of general psychology, as the phenomenon of replacement of target-image with the object-image [8, 10].

These findings confirmed once more the validity of scientific conceptions being developed by Soviet aviation psychologists, according to which instrument flying is not merely a matter of automated motor operations to track pointers.

A manuevered instrument flight is an extremely complex analytical and synthesizing activity of the brain, which requires that the pilot develop special mental actions, including elements of both graphic conceptions and parametrization of perceived information. However, there are still a number of unanswered scientific questions pertaining to mental control of actions and formation of integral conception of the flight situation. In particular, we still are not clear as to the hierarchy of construction and laws of transitions of the instantaneous method of information processing to processing in stages. The optimum correlation between clearness of informative signs and their quantitative expressions to facilitate formation of an integral image of a concrete "piece" of the flight situation must be established.

We wish to stress here that, in spite of the many investigations of visual perception of the information environment by the pilot, the problem of mental reflection remains pressing. Its successful solution depends largely on development of new and combined methodological procedures, including new equipment referable to taking films of the pilot's gaze.

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UDC: 612.172.1+612.824-088.53+616.12-008.3+612.12-008

CAPABILITIES OF ULTRASONIC METHODS OF EVALUATING HEMODYNAMICS OF CARDIOCEREBROVASCULAR SYSTEM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 1 Apr 85) pp 8-16

[Article by L. G. Simonov and M. S. Gelfenbeyn]

[English abstract from source] This paper reviews ultrasonic methods used at present to evaluate hemodynamic parameters of different organs and velocity characteristics of circulating blood. The ultrasonic methods make it possible not only to diagnose different vascular lesions but also to investigate the effects of unusual environmental parameters on the human body. The paper gives a classification of the existing and advanced procedures based on ultrasonic location when applied to determine hemodynamic characteristics of the cardiocerebrovascular system. The paper presents a description of ultrasonic methods used in studying the heart (velocity characteristics of the circulation of cardioelements), brain (pulse oscillations of vessel blood filling in the cranial cavity) and large arteries (blood filling and blood flow velocity).

[Text] As a rule, hemodynamic disturbances occur and develop in cerebral vessels in the presence of general involvement of the cardiovascular system, with which the self-regulating capacities of vessels with altered reactivity are considerably limited [18]. Thus, the degree of involvement of great vessels of the head plays an important part in onset of ischemic brain disease (IBD) [58, 61]. In such cases, impairment of cardiac hemodynamics and concomitant signs invevitably affect cerebral circulation. For example, in the presence of arterial hypotension, the decrease in delivery of blood to the brain and in linear velocity of blood flow lead to impairment of microcirculation, which is associated with signs of aggregation of formed blood elements and capillary stasis [32]. The chronic form of impaired cerebral circulation (ICC) is often associated with considerable changes in basic characteristics of central hemodynamics [18].

In the presence of ICC, early diagnosis and immediate, purposeful therapy are important, implementation of which is impossible without integral evaluation and monitoring of central and cerebral hemodynamics.

Both invasive and noninvasive methods are used to evaluate hemodynamics of the cardiocerebrovascular system (CCVS). Among the invasive methods, the following have gained the widest use: dye dilution method of Stuart-Hamilton, Kety-Schmidt method, polarography, radioisotope method, as well as cerebral angiography (CAG). These methods may be an additional traumatic factor for defense barriers of the body, and for this reason the performance of dynamic studies with their use is undesirable.

At the present time, development and use in different branches of health care of noninvasive methods is important; they offer vast opportunities for examining hemodynamics, obtaining reliable data concerning the patterns of regulation of central, regional and peripheral circulation under normal and pathological conditions.

One of the main criteria for evaluating hemodynamics is blood flow rate. The noninvasive methods used at present for this purpose are based on various physical principles, and they have a rather wide area of application (Table 1).

Table 1. Current noninvasive methods of evaluating central, regional and peripheral hemodynamics of organs and tissues

Physical methods	Method capability
Ultrasonic scanning	Evaluation of velocity of movement of cardiac elements, examination of pulsed perfusion of the brain, determination of blood flow rate in great vessels
Laser measurement of blood flow	Determination of multiparameter characteristics of blood flow in integumental tissues (peripheral vessels of the fingers and toes, oral cavity)
Optical plethysmography	Same
Nuclear magnetic resonance	Separate determination of blood flow in arteries and veins of the extremities

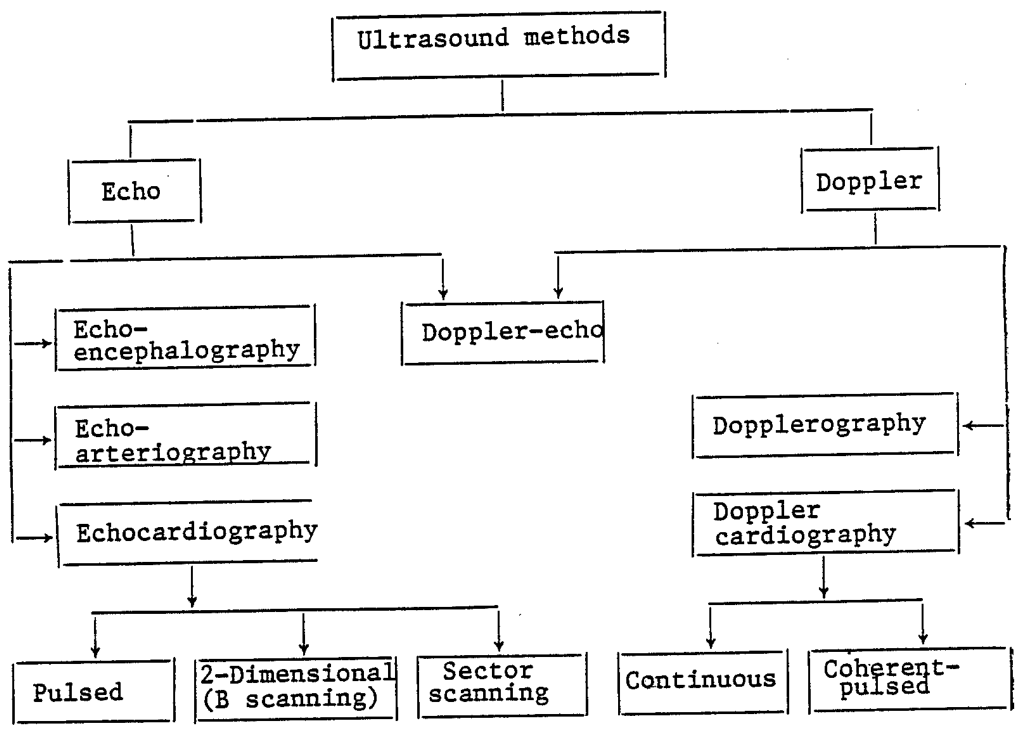
Ultrasonic methods (USM) are the most adequate for noninvasive studies of CCVS hemodynamics (see Chart and Table 2).

1. Ultrasonic Methods in Cardiology

Pulsed ultrasonic echo ranging was first used to examine the heart by Elder and Hertz in 1954 (cited in [36]). In the course of refinement of ultrasonic techniques, methods of one- and two-dimensional echocardiography, as well as real-time sector scanning, were developed. Ultrasonic echo ranging methods permit evaluation of the trajectory of movement of the principal cardiac elements on the path of an ultrasonic beam and determination of stroke volume and ejection fraction [44]. It was shown that the results of echocardiographic studies of left ventricular volume coincide with the results of invasive determination of volume by the method of ventriculography [60]. Feigenbaum [44] observes that, in patients with IBD, the volume and diameter of the left ventricle at the end

of the systole and diastole increase proportionately to severity of the disease. For this reason, many authors stress that pulsed echocardiography plays an important role in assessing the functional state of the heart and its reserves with physical loads [42, 59, 64].

Classification of ultrasonic diagnostic methods of examining the CCVS



Unlike the M mode (M--motion), in which a record is made of movement of cardiac elements on the path of the ultrasonic beam, in the two-dimensional mode it is possible to obtain true images of the transverse and longitudinal sections of the heart [36, 45, 52].

Thus, with ultrasonic methods (echocardiography), it is possible to detect rather accurately and at the early stages heart diseases such as stenosis of the right and left atrioventricular ostia, heart tumors, prolapse of mitral valve cusp, as well as zones of myocardial involvement, etc.

However, the principle on which echo ranging is based, permits evaluation of velocity characteristics of the hemodynamic system only by making calculations [12]. The Doppler ultrasonic method was developed for direct determination of velocity characteristics of movement of cardiac elements [50, 62]. In essence, this method consists of measuring the velocity characteristics of moving structures and blood by means of detection of change in frequency of emitted and reflected signals. All of the main structures of the heart (ventricular walls, septum, elements of the valvular system) are involved in formation of the

Doppler cardiogram. The sections of the spectrum characterizing movement of each of the scanned cardiac structures can be singled out by spectral analysis [1, 2]. It has been established that the velocity characteristics of movement of the posterior wall of the left ventricle reflect the most fully the functional state of the myocardium [12]. The velocity of the posterior wall of the left ventricle constitutes a mean of 4.8 cm/s in systole and 5.8 cm/s in diastole. In patients with ischemic heart disease, these values are reliably lower, 4.0 and 4.5 cm/s, respectively [14].

Table 2. Capabilities of ultrasound methods in studies of hemodynamic characteristics of different elements of the CCVS

Methods	Heart	Brain	Extracranial great vessels of the head
Echo	Echocardiography: geometric dimensions of ventricles, stroke volume	Echoencephalography: pulsed perfusion of cerebral hemispheres	Echoarteriography: linear dimensions of vessels
Doppler	Doppler cardiography: velocity of cardiac elements	Doppler encephalography: not formulated as a method at this time	Dopplerography: blood flow rate in arteries and veins separately
Doppler-echo	Doppler echocardiography: not formulated as a method at this time	Doppler encephalography: not formulated as a method at this time	Doppler echoarteriography: determines volumetric blood flow

Other parameters are also informative in the case of ultrasonic Doppler cardiography (DCG): dynamics of cardiac output [10], dynamics of effective coronary blood flow [3-5], measurement of velocities of cardiac elements [31], energetic correlations between contractility of the myocardium of the anterior and posterior walls of the left ventricle in systolic and diastolic phases [51].

When used during load tests, ultrasonic DCG can detect the degree and stage of cardiac insufficiency [6, 14].

Ultrasonic coherent-pulsed DCG is gaining increasing use; it combines the capabilities of pulsed echocardiography and continuous DCG [13], which permits measurement of the velocity and direction of movement of a selected cardiac element at depths of up to 140 mm, as well as degree of myocardial displacement. At the present time, coherent-pulsed DCG is being used with success for noninvasive evaluation of blood flow rate in the heart and aorta [38]. Steingart et al. [63] demonstrated that coherent-pulsed DCG permits evaluation of stroke volume. It is also used for integral evaluation of relaxation and contractile processes of the myocardium during exercise in the mode of measuring velocity of the posterior wall of the left ventricle [26].

2. Ultrasonic Echo Ranging in Studies of Intracranial Hemodynamics

Several works deal with one-dimensional echoencephalography for diagnosis of cerebrovascular diseases [15]. However, the shift of the medial echo signal

demonstrable by this method and other diagnostic criteria do not permit making an unambiguous determination of the condition of cerebral vessels, and they do not yield information about cerebrospinal fluid dynamic characteristics.

G. S. Strykov [29] established that, with instrumental implementation of the method, about 91% of the loss of ultrasonic energy is referable to reflection and dissipation in cranial bones and only 9% is absorbed. This author showed that a decrease in perfusion of the brain due to angiospasm or increased venous efflux leads to diminished absorption of ultrasound in the brain, whereas with increase in perfusion (when there is difficulty in venous efflux) there is greater extinction of ultrasound. Thus, the extinction of ultrasound in biological media could have information about hemodynamic and morphological characteristics of the tested region. Furthermore, ultrasound methods permit demonstration of functional insufficiency of cerebral hemodynamics, which is not always demonstrable by CAG [33].

In 1955, Lensell [57], who studied the pulsating nature of amplitudes of echo signals reflected from cerebral structures, discovered that these changes are synchronous with changes in heart rate. Vertical (amplitude) oscillations of the echo signal were based on changes in intensity of ultrasound reflected from pulsating structures.

In 1961, Braak et al. [39] discovered horizontal pulsations. These pulsations of echo signals reflect movement of the ranged structure in relation to the plane of the ultrasonic sensor. Horizontal pulsations are less marked than vertical ones. The authors commented on the technical difficulty of isolating and recording them [23].

N. K. Bogolepov et al. [15] report that arterial and venous blood flow, as well as pulsation of spinal fluid pressure, are the cause of echo signal pulsation.

Yu. Ye. Moskalenko et al. [19] believe that the increase in amplitude of pulsation may be related to the increase in amplitude of central venous pulse or decrease in tonus of cerebral arteries. Both a decrease in amplitude of pulsed fluctuations of pressure in arteries at the base of the skull and an increase in tonus of cerebral vessels as a result of release into the blood stream of vasoconstrictive substances, as well as drastic increase in venous perfusion, may be the causes of diminished amplitude of pulsations.

L. G. Simonov [26] proposed a method of one-dimensional ultrasonic echo ranging for evaluation of intracranial hemodynamics, which differs from the preceding methods in that the author ranged the brain in the forehead-occiput direction from the frontal tubers, selection and analysis being made of echo signals reflected from the occipital bone, in the formation of amplitude and phase characteristics of which the lateral ventricle of the brain was involved. As shown by experiments with models and phantoms, as well as comparative invasive and noninvasive studies [27, 28] and clinical observations of patients with various types of brain involvement, this method furnishes information about mechanical displacement of the walls of the lateral ventricle of the brain, which is a reflection of the state of pulsed perfusion of the cerebral hemispheres. At the same time, the echo ranging method was effective in examining the vascular system, particularly the extracranial part of the carotid arteries.

Bushmann [40, 41] was the first to use one-dimensional echography to determine the state of the carotid arteries; he ranged various segments of the carotid artery on the neck using an echoophthalmograph with ultrasonic sensory (at a frequency of 10 mHz). He described the echogram of the carotid artery in the form of two echo signals, the distance between which corresponds to the lumen of this vessel. Determination was made of perfusion, elasticity and thickness of the arterial wall from the reflected signals, which changed in amplitude in systole and diastole. Analogous clinical and experimental studies were conducted by Ye. V. Dorogova [11]. For arterial echography of the common carotid and internal carotid, she used a modified Echo-11 echoencephalograph. It was determined that the echo signal reflected from the isolated artery has the elements of an M-shaped complex. The nature of the recorded echo signal changed with change in diameter of the artery, pathological changes in the wall and occlusion of the vessel.

One-dimensional echography of the extracranial segment of the carotid was used in combined studies of intracranial hemodynamics [7, 11]. Here, the main diagnostic criteria were the amplitude of pulsation of echo signals from the carotid and its assymetry when sounding symmetrical parts on the left and right [11].

Systems of two-dimensional B scanning of the carotid in real time were developed, which are analogous to sector scanning in cardiology, which permit obtaining a clear image of longitudinal and transverse sections of the carotid from the clavicle to the mandible.

At the present time, there are no readily available noninvasive methods for examining the intracranial part of the cerebrovascular system. There are some ambiguous, somewhat contradictory evaluations in the literature of feasibility of examining intracranial hemodynamics by means of ultrasonic pulsography of cerebral brains [23-25, 57, 63].

It was found [47, 48] and theoretically validated [8, 43] that a change in diameter of a vessel leads to a change in area that reflects ultrasound. In addition, a change in density and elasticity of a vessel alters the reflection factor of ultrasound. It is known [46] that optimum reflection of ultrasonic energy occurs at medium interfaces, the difference in velocity of propagation of ultrasound in which exceeds 10 m/s. It is also known that the velocity of ultrasound in the carotid walls is 1647 m/s, it is 1520 m/s in brain matter and about 1500 m/s in cerebrospinal fluid.

For this reason, in spite of the relatively small dimensions of intracranial arteries, there are possibilities for detecting them with ultrasound.

In the mid 1960's, there were reports of using ultrasound to record pulsations in parts of deep-lying cerebral arteries [46-48]. It was indicated that it is possible to use ultrasound on the internal carotid in the bottom segment of the siphon, as well as different parts of the vertebral artery [47]. In the presence of thrombosis of the internal carotid artery, the authors observed absence of pulsations of the echo signal reflected from it, and in the presence of stenosis, marked deformity of pulsograms.

A. N. Fleyshman [30] developed a method of recording intracranial pulsating venous echo signals. He found that pulsation of venous echo signals diminishes with elevation of intracranial pressure.

G. I. Eninya and V. Kh. Robule [34-35] modified the method of ultrasonic echopulsography of vertebral arteries [8] to examine intracranial vessels, which consisted of recording pulsations of different fragments of a vessel. The authors use this method to determine the baseline state of intracranial arteries and diagnose onset of hemodynamic insufficiency.

Freund et al. [49] determine the rate of pulse wave propagation from the arch of the aorta to the ranged artery by evaluating the dynamics of lag time of the pulse wave in relation to timing of the cardiac cycle (i.e., determining the interval between appearance of R wave on the electrocardiogram to start of elevation of echopulsogram).

Thus, there is no doubt as to the importance of one-dimensional pulsed ultrasonic echography for evaluation of hemodynamic characteristics of both extra- and intra-cranial vessels. It is possible to evaluate pulsed perfusion of the cerebral hemispheres; the echopulsographic criteria of cerebrovascular diseases are informative, and they permit prompt detection of hemodynamic insufficiency, dynamic observation of hemodynamics and forecasting the results of therapeutic measures.

3. Ultrasonic Dopplerography for Evaluation of Condition of Great Vessels of the Head

Among the existing noninvasive methods, ultrasonic dopplerography occupies a special place and is gaining wide use. The advantage of Doppler methods, of which there are several modifications (ultrasonic, Doppler ateriography, Doppler spectroanalysis of carotid blood flow and real-time B scanning, combined B scanning, Doppler analysis of blood flow in duplex mode) is that they can be used to reliably distinguish between all of the principal forms of vascular pathology, differentiate between stenosis of the internal carotid artery and its occlusion, evaluate the degree of stenosis, which is important to determining the tactics of treatment and screening patients for angiography.

Evaluation of carotid flow by ultrasonic Doppler detectors of velocity is the most accurate noninvasive method of detecting occlusive disease of the carotid. This method is more sensitive than the periorbital method, since it can detect stenosis that does not disrupt blood flow in the orbital artery. Direct examination of the carotid permits localization of lesions in different parts of the artery on the neck. This method is particularly informative when combined with compression tests, with which stenosis of the carotid siphon can be found.

Doppler instruments for continuous and pulsed ranging, with combined and separate transformers, with and without singling out the direction of blood flow, have been developed and are in use for ultrasonic dopplerography [20].

Detection of occlusive involvement of extracranial segments of the carotid has been made possible by development of ultrasonic dopplerography. The reliability of this method (with angiographic monitoring) constitutes 99% in the

case of occlusion of the carotid and vertebral artery, 76.6% with stenosis of the carotid and vertebral artery, 70.6% in the presence of pathological tortuosity of the internal carotid and vertebral artery [17, 21, 37].

With reference to the question of desirability of ultrasonic dopplerography in the case of PICC (peripheral impairment of cerebral circulation), Muller (cited in [17]) voiced the opinion that this group of patients should be submitted only to CAG, whereas Keller et al. [55] validate the need for ultrasonic information about hemodynamics, regardless of the type of ICC.

We believe that ultrasonic dopplerography should be performed in all cases of PICC, and it should be the first stage in a comprehensive clinical work-up [17], since it is then possible to immediately pick up patients with marked pathology of great arteries, select an adequate method of CAG and define the tactics of therapy with validation.

The statement in the literature to the effect that ultrasonic dopplerography cannot entirely replace CAG is probably valid, but in routine practice, particularly with reference to outpatients, this method should apparently become the method of choice when examining patients with PICC.

If we consider the fact that any ICC can end with a cerebrovascular accident, the method of utlrasonic dopplerography should be used in those cases where an immediate diagnosis is required and CAG cannot be performed. This method permits institution of prompt and active thrombolytic therapy. Ultrasonic dopplerography may find application in mass screenings of a large number of people [21] with a high risk for cerebrovascular diseases.

The diagnostic potential of ultrasonic dopplerography has been studied considerably less for occlusive lesions of extracranial parts of the vertebral artery. This is attributable to methodological difficulties [16], since the vertebral artery is situated in the osseous-fibrous canal of the cervical spine at a considerable depth. In addition, there are many large arterial trunks of other vascular systems in the projection of the vertebral artery [53, 56].

When examining this artery in order to determine and prognosticate a patient's condition, attention is focused mainly on severity of asymmetry of linear blood flow rate (LBFR) in the vertebral artery, for which reason the coefficient of LBFR asymmetry was instroduced for this artery [37], which characterizes with rather high accuracy the condition of blood flow, starting with its complete absence (with 100% occlusion) and stenosis of varying degrees of severity to normal blood flow without asymmetry. Coincidence of diagnoses constitutes 80-99% for pathological states varying in severity.

The technique for ultrasonic dopplerography of the vertebral artery has been described in detail by Soviet and foreign authors [16, 21, 37, 56]. The most informative method involves placement of the probe on the anterior wall of the pharynx, where the artery is at a depth of 0.5-2.0 cm [9]. Stenosis is detected when there is more than 30% asymmetry of blood flow rate [37]. However, in the opinion of Yu. M. Nikitin [21], this method is time-consuming, since it requires special drugs to prepare patients for the test and it is not always applicable for the seriously ill.

Use of ultrasonic dopplerography in surgery of the cerebrovascular system permits detection of patients with high risk when there are asymptomatic occlusive lesions of the carotid artery. Such patients are often encountered among candidates for major reconstructive vascular surgery (aortocoronary shunts, peripheral arteries).

Carotid ultrasonic dopplerography is quite informative for intrasurgical monitoring during endarterectomies, and it permits evaluation of the reconstructed artery, as well as prompt elimination of technical defects of the operation before development of complications.

Ultrasonic dopplerography is quite effective in postoperative monitoring of the function of microvascular extra-intra-cranial anastomoses [22], since one can do without a check angiogram in this case.

Ultrasonic dopplerography can be used with success for measurement of arterial pressure (BP). Kardon et al. [54] proposed a method of measuring systolic and diastolic pressure based on the Doppler effect. Pressure can be determined even when Korotkov sounds are not audible, and the margin of error is 2-4 mm Hg.

At the present time, Doppler-echo (duplex) systems have been developed to examine the great vessels of the neck. A duplex system permits visualization of vascular margins, determination of blood flow in vessels, and it furnishes information about occlusion and plaques in the common, internal and external carotid artery.

Thus, one can record movements of the heart and its valves, determine blood flow in great and peripheral vessels by means of modern noninvasive methods. Ultrasonic cardiography can be used to detect cardiovascular insufficiency, local lesions to the heart, for additional monitoring of cardiac function, in particular, during flights in aircraft or spacecraft.

Ultrasonic dopplerography can be the first stage in working up patients with ICC (particularly outpatients) in order to detect those requiring CAG. At the same time, it can be used to monitor the function of an extra-intra-cranial anastomosis, as well as to check blood pressure.

It is believed that ultrasonic methods that permit evaluation of hemodynamic characteristics on different levels of the CCVS will be helpful in the study of hemodynamic interactions between the heart and brain.

It is possible to make broader use of ultrasound methods for purposes of preventive examination and occupational screening by virtue of their noninvasiveness, which permits numerous and prolonged tests, as well as the quantitative nature of the obtained data. However, it must be noted that it is desirable to perform prolonged tests, as well as monitoring of different parts of the cardiovascular system using ultrasonic methods in the presence of appropriate systems of immobilizing sensors that allow for manual or electronic guidance, or else scanning.

As can be seen from this survey, ultrasonic methods have advantages that permit their use to solve problems of practical health care and space medicine.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

UDC: 613.693-07:612.821.1/.3

PSYCHOPHYSIOLOGICAL ASPECTS OF COLOR-CODING OF FLIGHT AND NAVIGATION INFORMATION ON ONBOARD ELECTRONIC DISPLAYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 3 Jul 85) pp 16-19

[Article by A. A. Oboznov, A. N. Boyarskiy, and S. I. Buturlin]

[English abstract from source] Psychophysiological characteristics of pilots were compared when they used a color or a black-and-white electronic indicator in simulating a landing approach on a pilot trainer. No significant differences were seen in the objective evaluations of the visual function or in the precision with which the prescribed flight profile was maintained. However, subjective preferences were given to the color indicator. When the task was more complex (simulation of the deviated landing course), the time spent on looking for significant symbols and on recovering the necessary course decreased, if the pilots used a color indicator. It is concluded that the use of a color indicator can be redundant in performing simple tasks and therefore indifferent for pilot activities but it can be useful in performing complicated tasks when the pilot has to make a precise and quick assessment of the situation.

[Text] Development of onboard multifunction displays based on multicolor cathode-ray tubes [5] has heightened interest in the question of desirability of color coding flight and navigation parameters. An answer to this question depends largely on the extent to which color coding would increase the speed and accuracy of pilot perception and processing of information about the flight parameters. According to data in the literature, investigations of color coding were conducted, as a rule, under laboratory conditions and as related to tasks of searching for and identifying targets on screen displays. For example, in one of the foreign surveys, 42 such studies were analyzed, which had been conducted in the United States alone from 1952 to 1973, and demonstrated the definite advantages of color coding over other achromatic signs [6]. There have been few works dealing specially with the desirability of using colors to code flight and navigation parameters on onboard electronic displays [7-9]. On the one hand, the results of these studies failed to demonstrate advantages of multicolor displays over single color ones from the standpoint of improving speed and accuracy of pilot perception of piloting and navigation information, or efficiency of his performance. On the other hand, it was shown that pilots

subjectively assessed the multicolor displays as being "more attractive and esthetic" [9].

These conclusions are in agreement with data to the effect that use of color coding gives subjects greater confidence in their actions and facilitates performance of a task, although it does not affect the achieved result [10]. Since the disagreement between objective and subjective evaluations makes it difficult to unequivocally select the optimum variant of data coding on on-board electronic displays (monochromatic or multicolor lighting up of symbols), it is necessary to determine the causes of this disagreement. As compared to monochromatic indicators, the subjective preference of multichromatic ones may be attributable to a number of factors: physiological (difference in effect of monochromatic and multicolored lights on functional state of the visual analyzer), psychological (different content of mental image controlling pilot's actions), esthetic qualities, etc.

Our objective here was to make a comparative evaluation of the following characteristics of pilot performance with two variants of electronic display lights--green and green-yellow-red: speed and accuracy of pilot perception of flight and navigation information, precision in holding landing approach path, distinctions of mental regulation of pilot actions, functional state of the pilot's visual analyzer.

Methods

Six test pilots participated in the experiments, which were conducted in a flight simulator. Their task involved performance of an approach in accordance with attitude director signals. External illumination was at 7000 lux during the tests. We recorded the following parameters: precision in holding to the landing trajectory, distribution of attention among the dials (by means of filming the direction of their gaze), speed of reading instrument dials.

In some cases, we simulated a more difficult situation--"digression" of the aircraft from the landing pattern. This was effected in the following way. While making a landing according to the attitude director signals, the display was turned off for several seconds, after which "digression" from the landing pattern was simulated on the instrument dials. The display was then turned on again and the pilot's tasks were to assess the situation very rapidly and complete a successful landing. The rate of assessment of the situation was determined from the time the pilot spent on searching for and locating on the indicator screen the director symbol, with the help of which he performed subsequent piloting actions.

A set of tests was used to determine visual perception time, contrast sensitivity, critical flicker fusion frequency and acuity of color discrimination, in order to assess the functional state of the visual analyzer before and after 1-h "flying." The adequacy and informativeness of these tests had been proven in previous investigations [2].

Results and Discussion

Analysis of the results failed to demonstrate reliable differences between the recorded parameters as a function of variant of display lights (Tables 1 and 2).

Table 1. Comparative evaluation of pilot actions with two variants of electronic indicator lights (averaged data)

Parameter	Variant	
	1 color	multicolor
A. Objective assessment:		
probability of holding to landing path (Ek)	0.998	0.992
time of fixing gaze on dials, s	0.4-0.7	0.4-0.7
time for reading dials, s	0.8-1.3	0.8-1.3
erroneous readings, %	6.4	6.1
B. Subjective assessment:		
preferred variant of display lights	-	+*
for piloting	-	+*
for evaluation of aircraft's position in relation to landing path	-	+

*One of the six pilots had no preference for either variant.

Table 2. Parameters of functional state of visual analyzer with two variants of electronic light colors (M±m)

Parameter	Variant	
	1 color	multicolor
Visual perception time, s	0,162±0,013* / 0,182±0,014	0,167±0,011* / 0,188±0,016
Contrast sensitivity, rel.units	21,4±1,4 / 23,1±1,9	19,3±1,1 / 20,6±1,3
Critical flicker fusion frequency, Hz	29,1±1,3 / 29,0±1,3	28,6±0,8 / 29,2±1,4
Acuity of color discrimination, rel.units: for red	16,8±1,3 / 17,3±1,4	17,6±0,6 / 17,9±0,9
green	16,6±16,0 / 16,5±1,3	16,4±1,7 / 17,0±1,4
blue	16,4±1,2* / 17,9±1,2	16,5±1,7* / 17,4±1,6

Note: Values before flight in numerator and after flight in denominator. Asterisk indicates $P<0.05$.

The data listed in Table 1 (A) indicate that the precision of holding to the landing path, as well as speed and accuracy of reading instrument dials, are unrelated to the variant of display light colors.

According to Table 2, after flying for 1 h in both variants of indicator lighting there is equally marked insignificant decrease in functional state

of the visual analyzer, which is apparently related to diminished lability and sensibility of central parts of the visual analyzer [3].

Although differences were not demonstrated according to objective parameters, according to the pilots' subjective assessments the multicolor variant was preferable (see Table 1, B). Consequently, our data also revealed a discrepancy between objective and subjective assessments of desirability of color coding piloting and navigation information. Since the changes in state of the visual analyzer were unrelated to the variant of electronic display lights, the cause of discrepancy was related to other factors, primarily the distinctions of mental control of pilot actions [4]. The fact of the matter is that the mental image that controls operator actions is "redundant," i.e., the image always reflects more features of an object than needed to perform concrete operations. Even elementary stimuli are reflected in man as being multidimensional and having a number of features [1]. Redundancy of the mental images results in high reliability of object perception in difficult situations when, instead of the customary features of an object that are generally used for its identification, others are perceived that were previously redundant. It can be considred that the color feature may be used under different conditions as being redundant, "superfluous," or as the principal and essential one for successful performance of an action. Evidently, in our study, as well as in the above-mentioned analogous studies, there was simulation of situations in which pilots used achromatic informative tags of symbols (shape, brightness, size, spatial position, rate of displacement of pointers) to control their actions. The color tag was redundant in the simulated situations. For this reason, in making a comparative assessment of the monochromatic and polychromatic variants of lights of electronic onboard displays, the rate of perception of the symbols was the same. Why then was polychromatic lighting subjectively preferred by pilots to assess the spatial position of the aircraft during piloting? Apparently, the presence of an additional distinctive tag (color) in the displayed symbols increases reliability of perception of information and gives the pilots greater confidence in the accuracy of their assessment of the flight situation.

This assumption was confirmed by the results of a series of experiments, in which there was simulation of a complicated situation--digression of the aircraft from the required descent path.

It was found that, with the multicolor lighting variant, mean time for finding and identifying the location of the director symbol was 17% shorter than with monochromatic display (1.2 and 1.4 s, respectively; this difference is statistically reliable, $P<0.01$). The faster assessment of the situation in the former case than in the latter made it possible to reduce the mean latency period of the first controlling movement to restore the landing heading (2.1 s for the polychromatic and 2.5 s for the monochromatic variants).

Consequently, there are grounds to believe that in the complicated situations we simulated the color tag used by the pilots as the main one had a substantial effect on the speed of their evaluation of the situation.

Thus, the main conclusion derived from this investigation lies in recognition of the different role played by color in enhancing reliability of pilot

perception and assessment of flight and navigation parameters. Under ordinary conditions that do not require quick and differentiated assessment of a situation, color as a rule is a redundant tag and does not affect the "output" parameters of pilot performance. However, in cases that require immediate assessment of a changed situation, the color tag is used actively by pilots to reduce perception (search) time for the most important symbols.

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UDC: 629.78:612.766.1-08

FORECASTING OPERATOR WORK CAPACITY DURING LONG-TERM CONTINUOUS WORK

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 24 May 85) pp 19-22

[Article by A. K. Yepishkin and A. I. Skrypnikov]

[English abstract from source] It is shown that the work capacity of operators performing continuously for 56 hours can be predicted on the basis of their EEG and HR. It is found that a drastic decrease of work capacity is preceded by a 20-30% increase of low-frequency (delta and theta) activity and a 15-40% decrease of high-frequency (alpha and beta) activity as well as by a simultaneous decrease of HR. These changes were revealed 1 to 4 hours before changes in the operator's work capacity.

[Text] Evaluation and prediction of work capacity are among the most important problems of industrial psychophysiology. As a rule, parameters of results of performance, as well as psychological, physiological and biochemical parameters of the most important functions are used for these purposes [1, 2, 6 and others]. However, in a number of cases the data on direction and extent of these changes were ambiguous and sometimes even contradictory. For this reason an effort was made to explore the possibility of predicting operator work capacity by means of such important physiological parameters as the electroencephalogram (EEG) and heart rate (HR).

Methods

We conducted 5 series of studies involving 3 operators 19-32 years of age in each of them, who presented no deviations of health status.

We simualted prolonged (56 h) continuous operator work. The choice of this work mode was validated by the fact that, under extreme conditions, there is the most vivid manifestation of changes in all human functions. The cyclogram of the tests was planned in such a way as to record the EEG and HR an average of 1 h before evaluation of performance parameters in the control system. Sensorimotor pursuit and compensatory tracking was used as the model of such work.

In performing pursuit tracking the operator's task was to track a light that moved in a circle on the screen of a cathode-ray tube at the rate of

50 ang.min/s, by means of guiding a dot cursor controlled by a lever. The operation of compensatory tracking consisted of superimposing the movable dot-cursor light over a stationary, specified "zero" mark and holding it there for 30 s.

The quality of performance was evaluated by the modulus of the mismatch vector between the stimulus and cursor. The EEG and HR were recorded on an ME-132 Nihon Kohden encephalograph with concurrent recording on a DTR-1204 magnetograph. For the EEG, the electrodes were placed bipolarly in the right and left frontal and occipital leads 10-20 according to the international system. By using collodion to secure the electrodes on the head, we did not have to remove them throughout the period of the investigation. Analysis of biopotentials was made using a Plurimat computer and a special program [9]. We assessed the frequency spectrum of EEG voltage in the zones of Δ, Θ, α and β waves. The obtained material was submitted to statistical processing by conventional methods, with determination of arithmetic means (M), their deviation (σ) and arithmetic mean error (m). Reliability of results was determined using Student's t criterion.

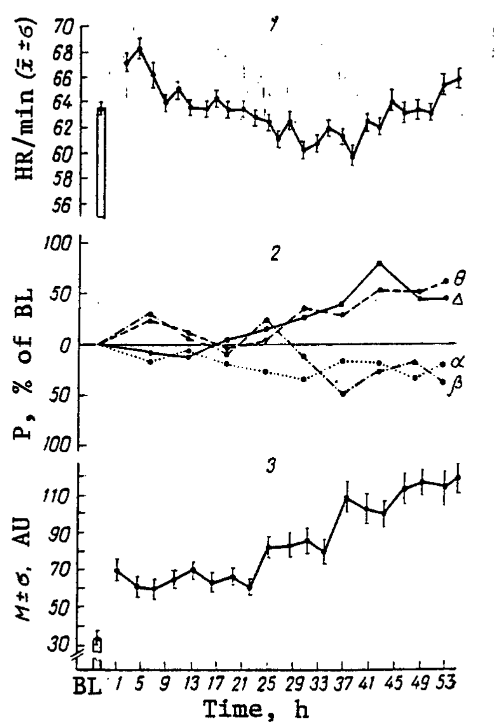

Figure 1.

Dynamics of HR (1), EEG wave voltage (2) and error of sensorimotor tracking (3) by operators in continuous work mode

Key, here and in Figure 1:
BL) baseline
AU) arbitrary units

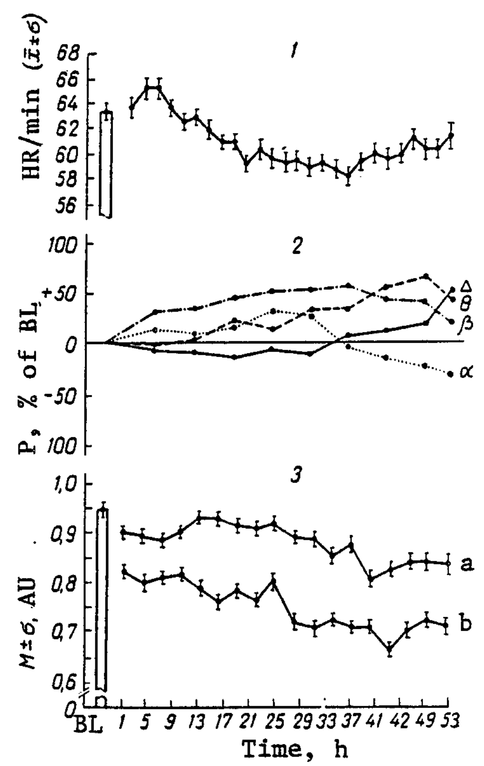

Figure 2.

Dynamics of HR (1), EEG wave voltage (2) and quality of compensatory tracking (3) by operators with use of AT stimulation in continuous work mode

a) quality of control with stimulation
b) tracking quality without stimulation

Results and Discussion

Figure 1 illustrates EEG and HR data for operators in the course of continuous performance. We were impressed by the presence of phases. The first phase (1st-6th h of study) is characterized by increased HR and energy of Δ and β waves on the EEG, which reflects prevalence of excitatory processes and tension of functional systems related to adjustment to the simulated working conditions. In the 2d phase (6th-24th h) there is some stabilization of bioelectrical activity of the cerebral cortex and heart rate near the baseline values.

The distinctive feature of the 3d phase (24th-36th h) is instability of heart rate parameters, their general means being lower than the baseline level. In this period, the EEG shows build-up of Δ and Θ activity with concurrent decline of α-wave activity. This pattern usually reflects a state of so-called "compensated" fatigue [8]. Subsequently (36th-38th h) there is increase in psychophysiological tension related to the need to perform planned work in the presence of marked fatigue. This is indicated by the significant (over 30%) increase in energy of Δ and Θ rhythms, with decrease in fast-wave activity and constant increase in HR.

The results of analysis of physiological parameters enables us to assume that the period of maximum efficiency would be referable to the first 24 h of the study. Thereafter, with increase in "central fatigue," operator efficiency will decline (with possible periods of relative increase). This assumption was confirmed when we analyzed the data on results of performance (see Figure 1). According to this figure, where the dynamics of error in performance by the operators of pursuit sensorimotor tracking, we see that the initial, reliable ($P<0.05$) increase in tracking error occurs in the 25th h of work, reaching a maximum (more than 3-fold increase) in the 37th-51st h.

In order to check the assumption about the demonstrated changes in HR and EEG in terms of qualitative performance characteristics, we tried to stimulate operator work capacity and then made a comparative analysis of the parameters in question. For this purpose, we used autogenic psychosomatic training, the beneficial effect of which on efficiency has been mentioned considerably in the literature [3-5, 7, and others].

Autogenic training (AT) was effected by pretrained operators every 6 h, starting with the first hour of work. The results revealed that the pattern of the tested physiological parameters of the operators and characteristics of their performance underwent specific changes. In the first place, the dynamics of HR were less marked than control data (without stimulation), although we did observe a tendency toward slowing of the heart rate up to the 36th h. It showed relatively unstable acceleration from the 38th h on (Figure 2). The EEG data, in turn, indicate that use of AT leads to slower development of inhibitory processes in the central nervous system. Throughout the 56 h of continuous performance, there was higher (as compared to control data) β activity, while the increase in energy of Δ rhythm occurred only after the 36th h of work. In general, the pattern of physiological parameters by the end of the study (38th-54th h) corresponds to "compensatory fatigue," which was recorded in the control series in the intervals between the 24th and 36th h (third phase).

In this period (after the 39th h), there is a decrease in quality of operator performance in the compensatory tracking system, as can be seen from the data illustrated in Figure 2. On the average, however, it is 17% higher ($P<0.05$) than in the control tests.

Thus, our results revealed that persistent decline of operator efficiency under the tested conditions is preceded by 20-30% increase in low-frequency (Δ and Θ) EEG activity and 15-40% decrease in voltage of high-frequency waves (α and β), with concurrent decrease in stability of heart rate. This reaction is already demonstrable 1-4 h prior to change in parameters characterizing performance.

The demonstrated signs may be considered prognostic with regard to operator capacity for a specified quality of performance.

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UDC: 629.78:612.821.1/.3-08

BIOCHEMICAL INDICATORS OF EMOTIONAL STRESS IN AIR TRAFFIC CONTROLLERS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 16 Apr 85) pp 22-25

[Article by Ye. L. Kan, V. A. Kupriyanov, K. F. Korovin, and O. O. Malinovskaya]

[English abstract from source] Air traffic controllers working in automatic and nonautomatic stations showed high values of lipid metabolism parameters as well as significant activation of the sympathoadrenal system (especially, its hormonal component). The level of the parameters under study was correlated with the workload.

[Text] The professional work of civil aviation air traffic controllers is associated with considerable nervous and emotional tension which, in turn, could serve as the cause of conflict and even emergency situations. The constant psychoemotional overload combined with such factors as disruption of biorhythms and hypokinesia are the cause of development of functional and later organic changes [2, 5]. In turn, it is known that the qualities of operators that are important to their profession, their mental efficiency, depend on the functional state of the body and are closely correlated with parameters of morbidity, primarily referable to the nervous and cardiovascular systems [4]. We report here the results of a study of the metabolic system of air traffic controllers in the course of routine professional work.

Methods

We examined 23 air traffic controllers at the Pulkovo Airport (20 to 30 year old men) who worked at nonautomated (1st group, 9 people) and automated (2d group, 4 men) air traffic control (ATC) stations. The functional state of the sympathoadrenal system (SAS) was evaluated according to epinephrine (E), norepinephrine (NE), dopamine (DA) and dioxyphenylalanine (DOPA) levels in batches of urine collected in 3-h periods of continuous ATC work on the day shift (0930 to 1230 hours). Data obtained for these parameters in batches of urine collected for the same period of time on days off served as the baseline [14].

Before and after working in the control tower (CT), we tested blood serum for some parameters of lipid metabolism: total lipids (TL) in reaction with sulfophosphovanillin reagent [11], total fraction of β and pre-β lipoproteins (LP)

by the turbidimetric method [7], total cholesterol according to Ilk (TC), free fatty acids (FFA) [10] and total phospholipids (TPL) [11]. On the day of the test, the subjects abstained from fatty food.

Results and Discussion

According to Table 1, both groups of controllers presented significant increase in both hormonal and mediator elements of the SAS during their ATC work. It is known [3] that a 2.0-2.5-fold increase, as compared to the baseline, in excretion of E in urine, 3.0-3.5-fold increase in NE excretion and 1.5-2.0-fold increase in DA excretion is indicative of development of an emotional stress reaction. Excretion of E increased by about 4.5 and 3.4 times in the 1st and 2d groups of controllers, respectively. There was not such a significant increase in NE excretion. Individual analysis of the findings revealed that its excretion increased by 3 or more times, as compared to the baseline, in 55% of the 1st group of subjects and 50% of the 2d group. Thus, the demonstrated changes in excretion of E (on the whole for each group) and NE (for about half the tested controllers) were indicative of development of a state that corresponds to marked emotional tension.

Table 1. Catecholamine and DOPA excretion (ng/min) during work of controllers at CT of Pulkovo Airport

Group	Work load	E		NE		DA		DOPA		NE/E		A+NE+DA/DOPA	
		BL	work	BL	work	BL	work	BL	work	BL	work	BL	work
1	16,5±±1,2	3,4±±0,8	15,4±±2,4*	12,9±±1,7	36,1±±3,7*	56,3±±6,7	79,6±±10,9	17,7±±3,5	17,6±±2,9	3,8	2,3	4,1	7,4
2	28,2±±3,0	4,7±±0,6	15,9±±1,2*	14,7±±1,4	36,0±±3,0*	55,6±±5,9	84,2±±8,5*	18,8±±2,1	17,5±±1,9	3,1	2,3	4,0	7,8

Note: Here and in Table 2, the workload is expressed by the number of boards controlled in the test period. Asterisk indicates P<0.05 in relation to BL [baseline].

It should be noted that the parameters of excretion of both catecholamines (CA) increased more in the 1st group of controllers. Both groups showed a decrease of NE/E, which was indicative of predominant activation of the hormonal part of the SAS, which was more marked for the 1st group.

According to data in the literature [3, 9], there is predominant increase in excretion of E in the presence of emotions related to repression of external reactions (fear, anxiety, depression). This is also confirmed by the results of studies conducted with use of a device for testing the effects of emotiogenic factors on mental performance of operators [15]. It was found that the rate of urinary excretion of A when working with an emotiogenic factor increased by about 70% and without it, by a mean of 30%. This was associated with disproportionate increase in NE excretion, as compared to E.

Thus, the demonstrated predominant activation of the hormonal part of the SAS in both groups of controllers and particularly the first is indicative of

intensity of the emotional component in overall intellectual and emotional tension.

The more marked increase in excretion of both catecholamines, particularly E, observed in the 1st group of controllers did not, however, correspond to the magnitude of the total workload in this group, which was reliably smaller (see Table 1) than in the 2d group. At the same time, we know from the literature [3, 9] that there is a direct relationship between E excretion and intensity of mental work. In our studies, we observed the reverse--the larger workload of the 2d group of controllers corresponded to less marked activation of the SAS. Consequently, the level of physiological expenditures for the performed work depended in a specific way on level of technical equipment of the ATC station, and it was lower for the 2d group of controllers.

The nature of changes in activity of mediator and hormonal parts of the SAS was compared to data in the literature concerning changes in activity of these elements in the presence of emotional stress in healthy subjects and patients with different grades of essential hypertension [13]. It was shown that, in the case of intense intellectual and emotional activity under laboratory test conditions, NE/E (judging by excretion of CA in urine) increased (by a mean of 18%) in healthy subjects, which was indicative of predominant activation of the mediator element of the SAS, and it decreased in different groups of patients (by a mean of 24%), which was indicative of predominant activation of the hormonal part of this system.

Consequently, the nature of changes in activity of SAS elements during the professional work of controllers is similar to the one demonstrable in patients with essential hypertension when submitted to an intellectual and emotional test load. It is known [17] that elevation of 24-h level of excretion of E is observed only at the early stages of development of essential hypertension and only in young individuals (up to 30 years). The increase in activity of the medullary layer of the adrenals occurs due to the stress factors (of occupational and nonoccupational genesis) that are instrumental in development of this disease in the presence of a nonunitilized reserve of synthesis of E.

According to the data in Table 1, both groups of subjects presented an increase in DA excretion and decrease in DOPA. The degree of increase in DA excretion in both groups was indicative to the one indicative of development of an emotional stress reaction. We found considerable increase in E+NE+DA/DOPA ratio, which is indicative of diminished reserve capacities of the SAS related to increased production of CA from DOPA.

Thus, the changes demonstrated in CA excretion in controllers during their professional work may be viewed as prognostically unfavorable and capable, under appropriate conditions (inadequate compensation of observed changes on their days off), of leading to development of pathological changes, primarily referable to the cardiovascular system.

Examination of the lipid spectrum of blood serum (Table 2) failed to reveal significant changes in parameters at the end of the ATC work period. In some cases, there was even a decline of the tested parameters, which is probably related to increased expenditure of lipids by tissues [8]. However, in most

cases the parameters were either close to the top of the normal range or even above it by the end of the work period in both groups of subjects. We also observed a decline of TPL/TC indicative of increase in atherogenicity of lipid composition of blood serum (the drop of TPL level in blood serum is instrumental in lowering colloidal stability of cholesterol). The TPL/TC ratio was less than 1 even before starting to work, and by the end of the work shift there was an even greater decline in both groups.

Table 2. Parameters of lipid metabolism of air traffic controllers at the Pulkovo Airport when working at the CT.

Group	TL, mg%		LP, mg%		TC, mg%		FFA, μg/eq/mℓ		TPL, mg%		TPL/TC	
	BL	work	BL	work	BL	work	BL	work	BL	work	BL	work
1	793,3± ±96,2	783,3± ±120,0	654,4± ±59,2	533,2± ±59,6	344,7± ±23,2	357,9± ±31,8	0,68± ±0,07	0,70± ±0,08	276,1± ±15,7	273,5± ±20,4	0,83± ±0,11	0,79± ±0,13
2	794,9± ±70,9	805,3± ±55,7	732,6± ±34,9	643,7± ±43,3	313,4± ±21,3	335,3± ±19,3	0,94± ±0,13	0,73± ±0,08	232,3± ±11,8	224,2± ±8,0	0,77± ±0,04	0,70± ±0,04

Individual analysis of the data obtained revealed that elevation and decline of TL parameter was observed in about the same number of subjects from each group. Most subjects of both groups presented a decline of LP: 7 out of 9 in the 1st group and 12 out of 14 in the 2d. In addition, there was a decline of TC in 4 subjects of the 1st group and 11 of the 2d group. FFA rose in 6 controllers in the 1st group and 4 in the 2d group. There was concurrent decline of TPL in most subjects of both groups.

Thus, there were high parameters of lipid metabolism in air traffic controllers of both groups, both before and after ATC work. We demonstrated in our preceding studies that air traffic controllers showed a significant increase in a number of parameters of lipid metabolism before the start of work on the CT, in their "prestart" state (in relation to day off) [6].

Significant changes in lipid composition of blood serum are observed in individuals in different occupations who are engaged in intense mental labor [1, 16], as well as with administration of E and NE in animal studies [12]. The pathochemical mechanisms of disturbances in lipid metabolism are based on changes in systems of neurohumoral regulation of metabolic processes. This applies, first of all, to changes in functional state of the SAS and the hypothalamo-hypophyseo-adrenocortical system.

Numerous clinical and experimental data lead us to believe that prolonged nervous and emotional tension eliciting significant changes in lipid metabolism is the principal factor in development of atherosclerosis.

Thus, the results of this study of activity of mediator and hormonal elements of the SAS revealed that the professional work of controllers at automated and nonautomated ATC stations leads to considerable nervous-mental and emotional tension, which can be assessed in many cases as emotional stress.

High activity of metabolic processes is associated with the high tension of regulatory mechanisms during ATC work, which is manifested by elevation of lipid metabolism parameters, the share of which increases considerably under such conditions.

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UDC: 629.78:612.014.477-063

TOLERANCE TO +Gz ACCELERATIONS OF INDIVIDUALS OF DIFFERENT AGES OTHER THAN PILOTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 13 Jun 85) pp 25-29

[Article by A. R. Kotovskaya, I. F. Vil-Vilyams, and V. Yu. Lukyanyuk]

[English abstract from source] Ninety-six healthy nonpilots, aged 21 to 50 years, were exposed to 228 rotations on a 7.25 m arm human centrifuge. The study demonstrated aged-related changes in +Gz tolerance of 3 to 5 G (for 30 s). The subjects at the age 31 to 40 years showed the highest tolerance while the subjects at the age 21 to 25 and 46 to 50 years the lowest tolerance. Young subjects (21-25 years old) often developed an asthenic type of the systolic pressure reaction in the ear lobe and visual disorders whereas older subjects (46-50 years old) displayed cardiac arrhythmias, lower heart rate and delayed recovery of blood pressure after exposure. It was also found that 60-80% subjects aged over 40 well tolerated acceleration of up to 5 G and therefore can be viewed as potential candidates for cosmonauts.

[Text] Refinement of space technology and expansion of the range of problems, solution of which is related to exploration of space, advances the tasks of involving specialists in different branches of science in spaceflights. This creates the conditions for expansion of the age range in screening cosmonaut-scientists. For this reason, there has been extensive discussion in the literature of recent years of the question of possible participation in spaceflights of qualified specialists 40 or more years of age [2, 7, 9].

At the same time, extremely few works have been published concerning investigation of tolerance to accelerations of individuals of different ages, including those over 40 years old. These studies were conducted mainly on flight personnel who have high tolerance to accelerations, and they are contradictory. For example, some authors reported decrease in tolerance to head-pelvis accelerations in healthy males over 40 years of age [4, 9], while others, on the contrary, stated that it increased with age [8].

Our objective here was to test tolerance to head-pelvis (+Gz) accelerations in healthy individuals other than pilots of different ages (from 21 to 50 years).

Methods

A total of 228 tests on a centrifuge with 7.25-m arm were conducted on 96 men in other than flight occupations, who were submitted to accelerations for the first time. All of the subjects, who were 21 to 50 years old, were distributed in 6 age groups at 5-year intervals.

We used +Gz accelerations as the functional load test, in the form of "plateaus" of 3, 4 and 5 G lasting 30 s each [4, 5]. The rate of build-up and decline of accelerations was 0.2 G/s with 10-15 min intervals between rotations.

In order to enhance tolerance to accelerations, all subjects were advised to generate static tension of muscles of the abdominal prelum and legs during rotation. The tests were conducted without use of antigravity devices.

Tolerance to +Gz accelerations was evaluated (good, satisfactory and low) by the method of P. M. Suvorov [5].

We recorded the following parameters in all tests: ECG in the three Nehb leads and monopolar thoracic leads V_1 and V_5 with subsequent calculation of heart rate (HR) and detection of cardiac rhythm disturbances, pneumogram, systolic arterial pressure (BP) in ear lobe vessels, systolic and diastolic BP in arm vessels according to Korotkov sounds, time of motor response to photic signals.

The obtained data were processed by the method of variation analysis with use of Student's t criterion.

Results and Discussion

The results of our studies revealed distinct age-related dynamics in tolerance to +Gz accelerations in nonpilots.

Exposure to accelerations of 3 and 4 G was tolerated well by all 96 subjects, regardless of age (Figure 1). Their general condition was good at these levels of accelerations, and no physiological functional disturbances were noted.

With exposure to 5 G accelerations, subjects 31 to 40 years old showed the best tolerance; in most cases (94%) their tolerance to such accelerations was good, and in only a few was it satisfactory. Satisfactory tolerance to +5 Gz accelerations was observed somewhat more often (11-20%) in subjects 26-30 and 41-45 years old. Those 21-25 and 46-50 years of age presented good and satisfactory tolerace in 18 and 20% of the cases, respectively, while others had low tolerance to 5 G accelerations.

These findings coincide with those of other authors [4] who observed a decrease in tolerance to +Gz accelerations in pilots under 25 and over 40 years of age.

With increase in age there was also a change in nature of symptoms that limited tolerance to accelerations (Figure 2). Thus, in subjects 21-25 years old, the

decrease in tolerance was attributed to drastic drop of systolic pressure and pulse amplitude in vessels of the earlobe to 40 mm Hg, as well as appearance of visual disorders, development of presyncopic state and loss of consciousness, i.e., symptoms related to inadequate delivery of blood to the brain.

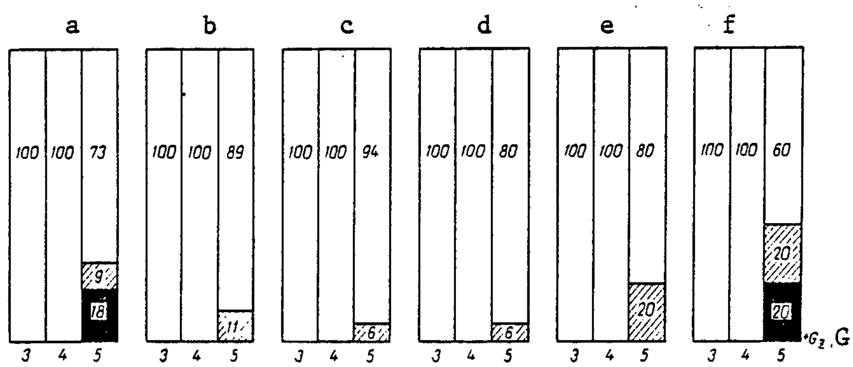

Figure 1. Tolerance to +Gz accelerations at 3, 4 and 5 G, for 30 s each (%), in nonpilots of different ages

Here and in Figures 2 and 4:

a-f) age groups, 21-25 (n = 11), 26-30 (n = 18), 31-35 (n = 16), 36-40 (n = 16), 41-45 (n = 10) and 46-50 years (n = 5), respectively

White bars—good tolerance, striped—satisfactory, black—low

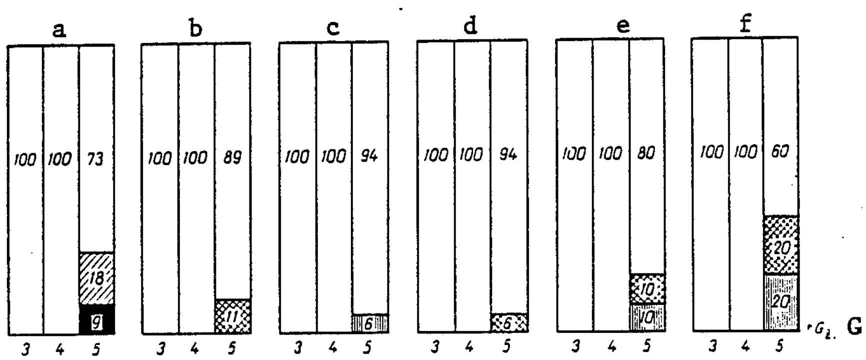

Figure 2. Criteria of diminished tolerance to +Gz accelerations at 3, 4 and 5 G, for 30 s each (%), in nonpilots of different ages

White bars—no symptoms of diminished tolerance to accelerations, black—loss of consciousness, diagonal stripes—impaired vision or its precursors, cross-hatched—cardiac dysrhythmia, vertical stripes—marked autonomic reactions

These disturbances were attributable to deficient mechanisms of regulation of the cardiovascular system and, first of all, vascular tonus under conditions of marked redistribution of blood and signs of vegetovascular instability.

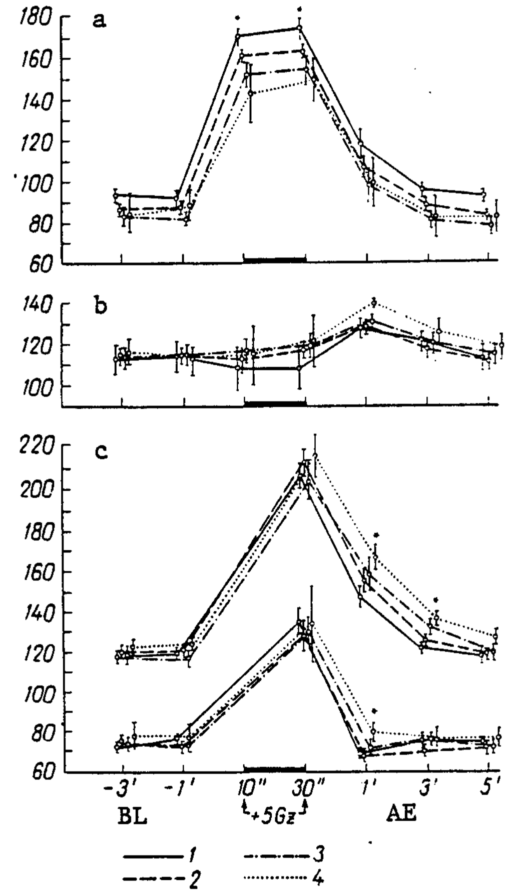

Figure 3.
Dynamics of cardiovascular parameters of nonpilots of different ages submitted to +5Gz in head-pelvis direction for 30 s

a) HR (per min)
b) systolic BP in ear lobe vessels (mm Hg)
c) top--systolic, bottom--diastolic

1-4) age groups of 21-25, 31-35, 41-45 and 46-50 years
BL) baseline
AE) aftereffect
*P<0.05, for 21-25 year data as compared to 46-50 years

With advance in age, disturbances referable to heart rate in the form of multiple, group or polytopic extrasystoles become the main limiting factor; they were found 1.5-2 times more often in the 46-50 year group than in younger subjects.

Evidently, the chief causes of these signs are age-related changes in structure, function and regulation of the cardiovascular system which, as also shown by other authors [1, 3], start to be distinct already after the age of 40-50 years. In this age period, the cardiovascular system undergoes a number of structural, metabolic and functional changes. One observes sclerosis and increased rigidity of the vascular wall, emptying of the capillary bed and decrease in number of functional capillaries, increased cardiac sensitivity to catecholamines, formation in the myocardium of sites of impaired metabolism and other processes. There is malcoordination of nervous system function, poorer brain nutrition and poorer delivery of blood to the brain.

All these and other changes can lead to diminished tolerance to functional load tests and, in particular, accelerations.

Investigation of cardiovascular system reactions to accelerations in older age groups revealed some distinctions.

With icnrease in age, we observed a reliably ($P<0.05$) less marked quickening of heart rate under the effect of accelerations (Figure 3). Thus, with +5Gz sinus tachycardia reached a mean of 172/min in subjects 21-25 years old and only 144/min in those 46-50 years of age.

In addition to mean values, with age there was also decline of maximum acceleration of heart rate (Figure 4). Sinus tachycardia at a level of 180/min or more was demonstrated in subjects 41-45 years old only with +5Gz accelerations and 4.5-5 times less often than in young people 21-30 years old, whereas in the 46-50 year group the HR never reached 180/min.

A similar decline of HR with age was described by many other authors [1, 6] in various functional load tests, which they attributed to age-related decrease in automatism of the sinus node.

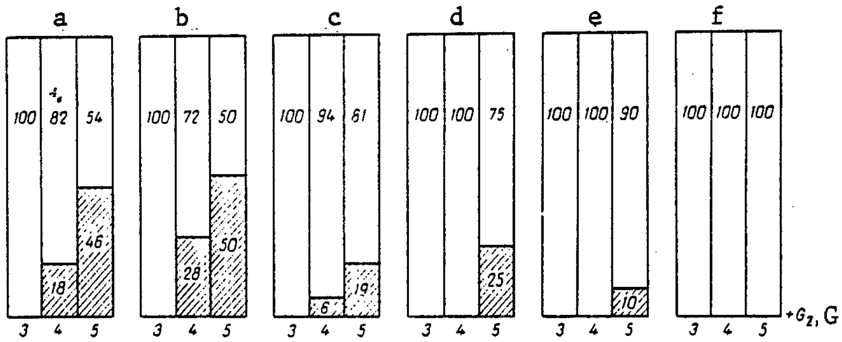

Figure 4. Incidence of sinus tachycardia (%) at the level of 180/min or more in nonpilots of different ages exposed to +Gz at 3, 4 and 5 G, for 30 s at each level

White bars--cases with HR of less than 180/min, striped--180/min or more

At the stage of braking the centrifuge after +5 Gz and in the immediate aftereffect period, subjects 46-50 years of age presented reliably (P<0.05) slower recovery of systolic and diastolic BP, as compared to subjects 21-25 years old (see Figure 3), which is consistent with findings of other authors [3].

In addition, after the centrifuge stopped, some subjects over 40 years of age showed development of marked autonomic reactions, such as pallor of the integument, hyperhidrosis and weakness. These signs were apparently due to decrease in the range of adaptive capabilities of the cardiovascular system in subjects of the older age groups.

Thus, this investigation revealed that there were age-related dynamics in healthy males other than pilots with respect to tolerance to +Gz accelerations ranging from 3 to 5 G. Highest tolerance was found in subjects 31-40 years old and lowest in the 21-25 and 46-50 year groups.

Age-related distinctions of physiological reactions were demonstrated, including disturbances that limit tolerance to accelerations. The asthenic type of BP reaction in vessels of the earlobe, development of functional visual disturbances and loss of consciousness were inherent in young men (21-25 years old), while disturbances typical of those over 45 years of age consisted of dysrhythmia, limited maximum HR and slowere recovery of BP after exposure to accelerations, which were indicative of some decline of functional reserves of the cardiovascular system.

At the same time, our findings indicate that, as applied to the factor we investigated--accelerations--there is a real possibility of allowing highly qualified specialists over 40 years of age to participate in spaceflights; as shown by our studies, in 60-80% of the cases they have good tolerance to +Gz accelerations up to 5 G. Individual expert evaluation of tolerance to accelerations of this category of individuals is particularly important.

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UDC: 629.78:612.843.363.1-08

VISUAL-OPTICAL ASSESSMENT OF THRESHOLDS OF OBJECT DISTORTION DUE TO LENS DEFECTS IN FLAT GLASS OF VEHICLE CABINS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 29 Apr 85) pp 29-33

[Article by A. V. Lekarev]

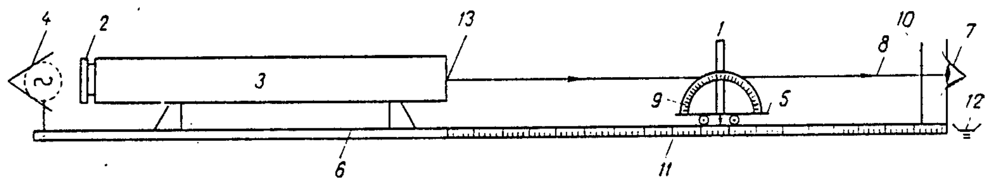
[English abstract from source] It has been shown experimentally that the threshold values of optical distortions of test objects projected by a collimator during binocular observation through the lens defects of vehicle transparencies depend on their dioptric value and sign, distance between the observer's eyes and the transparencies as well as on the angle of those latter. The experimentally derived dependence can be used to standardize optical parameters of vehicle transparencies.

[Text] Lens defects in the glass parts of vehicle (V) cabins can cause optical distortions of the outside viewed by an operator [1, 2]. They are manifested in the form of vague pattern and deformity of observed objects, impaired ability to gage the distance to them, their seeming movement [3]. According to the literature, the threshold level of optical distortion of an observed object depends on dioptric value and sign of the lens defect in the glass, area it occupies, angle in relation to viewing line, distance between the observer's eyes and the glass [4]. These functions were obtained by calculations, on the basis of laws of geometric optics with monocular viewing of the object. There are contradictory data in works dealing with definition of threshold values of optical defects in glass in the case of binocular observation by an operator of objects outside the cabin [5-7]. For this reason, our objective here was to investigate the thresholds of optical distortions of objects by lenticular defects in glass parts of vehicle cabins while an operator is observing binocularly test objects projected with a collimator device.

Methods

An OSK-2TsL collimator device (see Figure) was used for determination by an operator of threshold of optical distortion of an observed object. Positive and negative lenses ground on the surface of cabin glass with optical strength of 0.04, 0.08 and 0.12 D were used as glass defects. Lens diameter was 200 mm, which enabled the operator to observe the test object binocularly. Landolt rings *2* projected by collimator *3* by means of light *4* served as the test object.

Lenses *1* were secured in a special device *5*, which moved over track *6* to different distances from the operator's eyes *7*. Lenses *1* were exhibited at different angles to sighting line *8* by means of device *5*. The angle of the lenses was measured in a degree-based system with goniometer *9*. Visual estimation of optical distortion of the test object was checked with test ring *10*. The distance from the lenses to the operator's eyes was measured on metric scale *11* installed on the track. The operator's head was immobilized by means of chin rest *12*. Fixation point *13* was in the center of projection of the test object. The test object was compared discretely to the test ring using a timer connected to the lamp in the collimator illuminating device. The test object was observed for 0.1 s.



Schematic diagram of visual-optic device. Explanation given in the text

A total of 20 operators 19-20 years of age, with emmetropic refraction and 1.0 visual acuity in each eye, participated in the experiments. In all we made 316 tests. The data were submitted to statistical processing with 95% reliability of differences between means.

Results and Discussion

Table 1 lists the results of tests to determine the threshold of optical distortion of a test object as a function of optical strength and sign of lens defect in the glass, as well as distance to the observer's eyes.

Table 1.
Threshold of optical distortion of test object as a function of distance between observer's eyes and lens defects in glass which had different optical strength and sign (M±m)

Distance (mm) from observ.eye to lens		Optical strength of lens (D)	P
collect. lens (+)	diverg. lens (-)		
250±3,6	175±3,8	0,12	<0.05
425±5,6	315±5,9	0,08	<0.05
650±8,7	650±8,9	0,04	>0,05

Table 2.
Threshold of optical distortion of test object as a function of angle of inclination of lens defects in glass which had different optical strength and sign (M±m)

Permissble angle of lens (α°)		Optical strength of lens (D)	P
collect. lens (+)	diverg. lens (-)		
35±1,4	35±1,5	0,12	<0.05
35±1,5	35±1,7	0,08	<0,05
35±1,8	35±1,9	0,04	<0.05

As can be seen in Table 1, the threhsold of optical distortion for collecting and diverging lenses with optical strength of 0.12 and 0.08 D is at different distances from the observer's eyes, and with 0.04 D it is at the same distance. For collecting lenses with up to 0.04 D optical strength, the threshold of optical distortion is at longer distances from the observer than for diverging lenses. With decrease in optical strength, regardless of lens sign, there is increase in distance of threshold of optical distortion of the test object from the observer. With diverging lens defects in glass, optical distortions of angular dimensions of the observed object consist of decrease in their apparent size, as compared to real size and seemingly greater distance of the object from the observer; the reverse phenomenon occurs with collecting lenses. The diverging lens defects in glass elicit optical distortion of observed objects at shorter distances to the observer's eyes than collecting lenses (with the same optical strength), and it is only at 0.04 D that one can disregard the effect of the sign. Consequently, diverging lens defects in excess of 0.04 D present on vehicle cabin glass have a stronger effect on optical distortion of observed objects than collecting lenses.

Thus, with lens defects in glass at distances not exceeding the threshold of optical distortion of the test object, operators did not develop erroneous perception of changes in size of the observed object, as compared to its true dimensions, i.e., they were "optically empty." But as soon as the threshold of optical distortion of the observed object exceeded the "boundary," the operators reported a change in both angular dimensions of the observed object, as compared to its actual ones, and distance to it.

The obtained experimental data were approximated by the least squares method to third-degree polynomials:

$$D_{(-)} = 1.8\cdot10^{-1} - 4.3\cdot10^{-4}S + 3.5\cdot10^{-7}S^2 - 7.7\cdot10^{-11}S^3,$$ for diverging lens defects;

$$D_{(+)} = +2.1\cdot10^{-1} - 4.8\cdot10^{-4}S + 4.7\cdot10^{-7}S^2 - 2.3\cdot10^{-10}S^3,$$ for collecting lens defects,

where D is optical strength of lens defect in flat glass (in diopters) with different signs; S is distance from observer's eyes to lense defect in flat glass at which the observed object becomes deformed.

In this case, deformation of the observed object by lens defects occurs when they are as close as possible to the operator's eyes with optical strength of about 0.18 D for diverging lenses and 0.21 D for collecting ones. After finding the "boundary" of the threshold of optical distortion of the test object by lens defects in glass which were placed vertically in front of the observer in relation to the sighting line, it was necessary to establish, within the limits of the demonstrated optically "empty" zones, the permissible angle of inclination of the lens defect, in excess of which there is optical distortion of the observed object. The results of this study revealed that the angle of lens defects in glass, in relation to the vertical plane, must not exceed 35° for collecting and diverging lenses at the tested diopter levels (Table 2).

Consequently, for glass items that have lens defects on their surface with the above-indicated optical strength and sign, the angle of installation in vehicle cabins must be at least 55°.

Thus, our results enabled us to define a group of thresholds of optical distortion of an observed object by lens defects in glass when it is observed binocularly as a function of optical strength and sign of the lens defect, as well as distance from the observer and permissible angle in relation to the operator's sighting line. Considering the distinctions of the proposed method of evaluating thresholds of lens defects in vehicle cabin glass for the case of binocular observation by the operator of test objects projected by the collimator device, the obtained data can be used as tentative guidelines as to allowances for optical characteristics of flat glass. Since the visual problems an operator solves when driving a vehicle are much more complicated than the ones we have discussed, it is desirable to conduct further investigations under observation conditions that are close to real ones.

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UDC: 612.744.21-08:[612.2+612.121.3]-06:615.835.3

USE OF GAS MIXTURES WITH HIGH OXYGEN AND CARBON DIOXIDE CONTENT TO NORMALIZE EXTERNAL RESPIRATION AND BLOOD ACID-BASE EQUILIBRIUM IN PRESENCE OF MUSCLE FATIGUE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 30 Jul 85) pp 32-37

[Article by N. A. Agadzhanyan, N. P. Krasnikov, and S. I. Naydich]

[English abstract from source] Use of gas mixtures containing 1% CO_2 + 35% O_2 and 35% O_2 in the air during a passive rest after a high workload led to the neutralization of acid metabolites and recovery of acid-base equilibrium due to a greater oxygen consumption, retention of metabolic CO_2 in plasma and accumulation of endogenous CO_2 in body fluids.

[Text] In recent years, hyperoxic and hypercapnic gas mixtures began to be used increasingly often to accelerate correction of oxygen debt that occurs during intense exercise in the mode of anaerobic power in sports practice, and to improve physical work capacity of individuals [1, 4, 11]. It is known that, during physical labor, along with a shortage of oxygen there is a progressive shortage of CO_2, since intense muscular activity is associated with depletion of bicarbonate capacity of tissues, elimination of buffer carbon dioxide and development of metabolic acidosis. In a state of muscle fatigue, blood pH drops to a critical level, there is decline of p_aCO_2, which is indicative of impairment of equivalent ratio between buffer bases and significant decline of HCO_3^-. In the recovery period following intense physical exercise, there is accumulation of endogenous carbon dioxide, the reserve of which is expended in accordance with intensity of accumulation of acid metabolic products [20]. It was noticed that recovery of acid-base equilibrium occurs concurrently with elevation of CO_2 tension in alveolar air and arterial blood. In vitro studies demonstrated that it is possible to control the acid-base status of plasma by altering pCO_2 over the surface of fluid [13]. It was shown that, with increase in partial CO_2 pressure in air, there is more significant uptake of carbon dioxide by blood plasma, as a result of which there is formation of a large amount of carbonic acid and bicarbonates. The concentration of hydrogen ions in fluid will remain stable when there is a specific buffer ratio. Consequently, it is theoretically possible to control buffer capacity of blood and pH by means of selecting appropriate partial CO_2 pressure in inspired air.

Our objective here was to test the effect on man of different gas mixtures in order to assure speedy recovery of external respiratory function, gas exchange and acid-base equilibrium in the presence of physical fatigue.

Methods

Twelve qualified athletes (average age 16.8±0.8 years, height 166.7±2.0 cm, weight 60.3±1.6 kg, VC [vital lung capacity] 4250 80 mℓ, PWC_{170} 24.6±1.2 kg-m/min•kg, MOU [maximum oxygen uptake] 68.4±2.8 mℓ/min•kg). After four practice sessions on the bicycle ergometer, they were all included in the test program. Four series of tests at 48-h intervals were conducted on athletes in a state of fatigue. In the 1st series, we determined baseline data under ordinary atmospheric conditions. In the 2d series, the subjects breathed a gas mixture containing 1% CO_2 and 35% O_2. In the 3d series, we used a hyperoxic gas mixture (35% O_2) with normal CO_2 content; in the 4th series we tested the effect on man of high CO_2 content in inhaled atmospheric air (1% CO_2 + 20.9% O_2). The tests with the gas mixtures were conducted each time 20 min after the athletes performed a maximum physical load exercise. The subjects exercised at an increasing pace in order to reach their personal limit. The initial load was 50 W. It was increased by 50 W every 3 min until appearance of signs of profound fatigue and refusal to continue. The following were considered objective factors making it impossible to continue exercising: achievement of maximum oxygen uptake, increase in heart rate to a mean of 190/min, decline of capillary blood pH to 7.090±0.001 AU [arbitrary units], and profuse perspiration. After they refused to continue, the athletes were asked to work on the bicycle ergometer pedaling for 60 s at a 100-W load in order to avoid gravity shock. Then, after 20 min of passive rest, they inhaled a given gas mixture for 20 min in order to speed recovery of acid-base balance and external respiration. All of the exhaled air was collected in a meteorological probe, and determination was made of total oxygen consumed in the case of an altered gas environment. Parameters of pulmonary ventilation and exchange of gases were recorded by the Douglas-Haldane method in the 40th min of recovery while breathing with the different gas mixtures. We determined respiration rate (f), pulmonary ventilation (V_E), carbon dioxide output (VCO_2), oxygen uptake (VO_2), respiratory quotient (R), oxygen utilization coefficient (CUO_2). Acid-base balance was examined using an OR-210/3 microanalyzer by the equilibration method. Samples of capillary blood for analysis were drawn from the warmed finger during maximum exercise in the 20th and 40th min of the recovery period. We determined the following parameters: blood pH, amount of buffer bases (BB), nonvolatile acid excess (BE), actual (AB) and standard (SB) bicarbonates, total chemically bound and physically dissolved carbon dioxide (tCO_2), partial carbon dioxide tension in tested blood (p_aCO_2).

Results and Discussion

The total volume of exercise performed on the ergometer until the subjects reached a state of complete fatigue constituted a mean of 19,600 kg-m. About 50% of the exercise was performed in the presence of oxygen debt. Anaerobic glycolysis caused accumulation of lactate and development of decompensated metabolic acidosis (see Table). There were significant changes in the subjects characterized by decline of blood pH from 7.412±0.006 to 7.090±0.001 ($P<0.001$), accumulation of nonvolatile acids to 20.1±0.62 mmol/ℓ, decrease in

concentrations of actual and standard bicarbonates from 24.2±0.26 to 9.7±0.12 mmol/ℓ ($P<0.001$) and from 24.1±0.16 to 11.7±0.33 mmol/ℓ ($P<0.001$), respectively, decrease in tCO_2 from 25.0±0.18 to 9.9±0.12 mmol/ℓ ($P<0.001$) and decrease in pCO_2 of capillary blood from 52.6±0.52 to 42.8±0.82 gPa ($P<0.001$). Neutralization of metabolic products with involvement of buffer bicarbonate was associated by additional output of 9.4±0.6 ℓ nonmetabolic CO_2 and decrease in tissular CO_2 capacity. During passive rest under ordinary atmospheric conditions, we observed partial recovery of acid-base parameters. Along with increase in blood tCO_2 from 9.9±0.12 to 19.4±0.30 mmol/ℓ ($P<0.001$) and p_aCO_2 from 42.8±0.82 to 47.2±0.94 gPa ($P<0.01$), there was an increase in buffer bases from 27.9±0.73 to 42.1±0.44 mmol/ℓ ($P<0.001$), parameters of actual and standard bicarbonates from 9.7±0.12 to 18.5±0.35 mmol/ℓ ($P<0.001$) and from 11.7±0.33 to 21.4±0.26 mmol/ℓ ($P<0.001$), respectively, decrease in acid concentration from 20.1±0.62 to 5.7±0.52 mmol/ℓ ($P<0.001$) and rise in blood pH from 7.090±0.001 to 7.344±0.005 ($P<0.001$). Brief respiration with a gas mixture containing 1% CO_2 and 35% O_2 led to more marked changes in the tested parameters: nonvolatile acid content dropped from 5.7±0.52 to 4.2±0.38 mmol/ℓ ($P<0.05$), while buffer base content, on the contrary, increased from 42.1±0.44 to 43.6±0.42 mmol/ℓ ($P<0.05$); actual bicarbonate concentration increased from 18.5±0.35 to 20.0±0.33 mmol/ℓ ($P<0.01$); total chemically bound CO_2 increased from 19.4±0.30 to 21.2±0.28 mmol/ℓ ($P<0.01$); the parameter characterizing active blood reaction rose from 7.344±0.005 to 7.372±0.006 ($P<0.05$). About the same changes were noted with inhalation of a hyperoxic gas mixture containing 35% O_2. However, during breathing of atmospheric air with 1% CO_2 no reliable changes were demonstrable in acid-base balance.

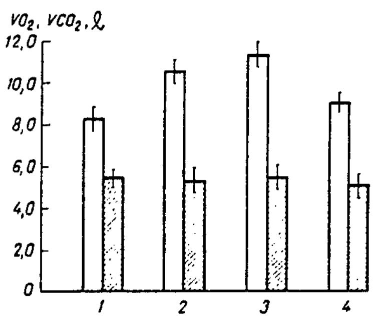
Parameters of external respiration and acid-base balance in athletes at relative rest, maximum exercise load, and 40th min of recovery period while breathing with different gas mixtures

Parameter	Baseline data	Maximum load	40th min of recovery while breathing with the gas mixtures			
			20,9 % O_2	1 % CO_2 + +35 % O_2	36,2 % O_2	1 % CO_2 + +20,9 % O_2
f, per min	14,6±1,2	46,6±1,8	16,4±0,9	16,8±1,2	16,7±1,0	15,0±1,4
V_E, ℓ/min	9,2±0,8	122,8±3,2	8,4±1,3	12,0±0,8*	12,6±1,0*	11,3±1,2*
VCO_2, mℓ/min	212,6±8,8	3886,0±156	174,8±6,8	216,3±12,5*	260,6±10,7*	232,0±12,2*
VO_2, "	260,4±12,0	4070,2±180	270,3±10,4	548,6±20,6*	577,2±25,0*	430,6±16,7*
R, rel.U	0,820±0,010	0,951±0,007	0,642±0,012	0,400±0,010*	0,446±0,02*	0,542±0,02*
CUO2, mℓ/ℓ	28,2±0,8	33,2±0,8	31,7±1,2	45,8±1,6*	46,0±1,6*	38,2±1,2*
pH, AU	7,412±0,006	7,090±0,001	7,344±0,005	7,372±0,006*	7,376±0,006*	7,348±0,005
BE, mmol/ℓ	+0,3±0,001	—20,1±0,62	—5,7±0,52	—4,2±0,38*	—3,7±0,32*	—5,4±0,41
BB, "	48,1±0,34	27,9±0,73	42,1±0,44	43,6±0,42*	44,4±0,37*	42,5±0,35
AB, "	24,2±0,26	9,7±0,12	18,5±0,35	20,0±0,33*	20,4±0,42*	18,7±0,38
SB, "	24,1±0,16	11,7±0,33	21,4±0,26	22,0±0,36	22,7±0,38	21,5±0,38
tCO_2, "	25,0±0,18	9,9±0,12	19,4±0,30	21,2±0,28*	21,4±0,44*	19,6±0,36
pCO_2, gPa	52,6±0,52	42,8±0,82	47,2±0,94	48,6±0,82	47,9±0,90	47,0±0,80

*Differences are statistically reliable in comparison to data found under ordinary atmospheric conditions in 40th min of rest.

The parameters of external respiration recorded under ordinary atmospheric conditions dropped to the baseline during passive rest, reflecting complete

compensation of oxygen debt. Use of gas mixture with higher O_2 and CO_2 content was associated with increase in pulmonary ventilation from 8.4±1.3 to 12.0±0.8 ℓ/min (P<0.005), oxygen uptake from 270.3±10.4 to 548.6±20.6 mℓ/min (P<0.001), carbon dioxide output from 174.8±6.8 to 216.3±12.5 mℓ/min (P<0.02) and CUO_2 from 31.7±1.2 to 45.8 mℓ/ℓ, and decrease in R from 0.642±0.12 to 0.400±0.010 rel. U (P<0.001). Inhalation of hyperoxic gas mixture was also characterized by considerable increase in exchange of gases. The tested parameters changed to a lesser extent with inhalation of air with higher CO_2 content.



General parameters of gas exchange in state of fatigue when breathing for 20 min with atmospheric air (1), hypercapnic-hyperoxic (2), hyperoxic (3) and hypercapnic (4) gas mixtures
White bars— VO_2, striped— VCO_2

The Figure illustrates the general parameters of gas exchange in a state of fatigue. A typical finding is that, in the case of an altered gas atmosphere, during passive rest after intense exercise VCO_2 constituted about 50% of VO_2, the respiratory quotient decreased, which is indicative of retention of endogenous CO_2 in the human body. Thus, the results of these investigations revealed that it is possible to control bicarbonate buffer capacity of blood by means of accumulation of endogenous CO_2 in the body.

Performance of intense exercise in our tests was associated with development of decompensated metabolic acidosis where, along with accumulation of anaerobic glycolysis and decline of pH to 7.090±0.001, we observed decrease in blood pCO_2 due to considerable expenditure of buffer bicarbonates in binding hydrogen ions. In the studies of a number of authors, they demonstrated a decline of pH after work to 6.8±6.9 U, drop of pCO_2 of arterialized blood to 18.6 gPa, increase in concentration of nonvolatile acids to 34 mmol/ℓ. There was a statistically reliable linear correlation between values of pH and BE [19]. With increase in lactic acid content to 30 mmol/ℓ, there is equivalent decrease in blood bicarbonate content virtually to zero [17]. The biochemical reactions of interaction of sodium bicarbonate with blood lactate led to breakdown of HCO_3^- and removal of buffer excess CO_2. In addition, during physical work exceeding the anaerobic threshold, the increase in pulmonary ventilation preceded oxygen uptake. In this case, hyperventilation develops, which leads to drop of arterial blood pCO_2 [25]. As a result of the body's loss of a large amount of metabolic and buffer CO_2, tissue hypocapnia develops and there is slower resynthesis of bicarbonates. During passive rest there is activation of physiological reactions causing decline of p_aCO_2, respiratory quotient and retention of metabolic carbon dioxide by blood plasma [8]. The recovery rate of parameters of acid-base equilibrium depends on severity of change in tissue chemistry. Under normoxic conditions, the duration of the recovery period is approximately proportionate to the square of lactate concentration in working muscles [20].

Various mechanisms that control gas homeostasis are triggered to restore partial CO_2 tension in blood and eliminate the oxygen debt. In a state of fatigue, p_aCO_2 decreases, minute volume and oxygen uptake drop to the baseline and there is elimination of oxygen debt, but metabolic acidosis remains uncompensated. The

difference in time of recovery of parameters of external respiration and acid-base balance is apparently due to the rate of restoration of p_aCO_2 as the main component in the system of metabolic regulation. Retention and accumulation of CO_2 in tissues during rest would help increase utilization of oxygen, accelerate neutralization of nonvolatile acids and restore acid-base balance.

The results of our studies revealed that brief respiration with a hyperoxic gas mixture in a state of fatigue was associated with moderate increase in pulmonary ventilation and gas exchange. Oxygen uptake increased by a mean of 37% over the entire period of inhalation, carbon dioxide output did not change, as compared to data observed under normal atmospheric conditions. Respiratory quotient decreased to 0.445±0.001 rel. U, which was indicative of retention of metabolic CO_2. However, partial CO_2 tension in blood remained stable at all times and did not exceed the physiological range. Consequently, the physiological reactions for self-regulation of gas composition of the endogenous environment provide for accumulation and distribution of metabolic CO_2 in organs and tissues without elevation of p_aCO_2. Body fluids may be the main reservoir for CO_2; they are capable of absorbing molecular CO_2 and changing it into a chemically bound state. The leading role in redistribution of CO_2 among organs and tissues is attributed to blood flow, since when there is complete oxygenation of hemoglobin its physical dissolution in plasma and increased rate of circulation become the principal means of displacement of CO_2 [22]. As oxygenation of hemoglobin increases, its affinity for oxygen increases by about 500 times. In such a case, virtually all of the hemoglobin is excluded from the former functional rhythm and becomes incapable of transporting oxygen and CO_2 [5, 6]. Under hyperoxic conditions, there may be a decrease in tissular metabolic processes due to diminished utilization of oxygen because of its vasoconstrictive effect and slower capillary blood flow [7].

The faster recovery of bicarbonate capacity of blood and neutralization of excess nonvolatile acids in our studies were probably due to increased O_2 uptake and accumulation of metabolic CO_2 with decrease in transport function of blood for CO_2 under hyperoxic conditions.

It has been shown in the works of some authors that there is oxygen-free neutralization of lactate in the liver and muscles during gluconeogenesis, i.e., during formation of glucose from noncarbohydrate compounds, such as pyruvic acid and lactate [21]. A significant part of the lactate and pyruvate is transformed during gluconeogenesis into glucose, which is then utilized as the energy substrate for skeletal muscles. Elimination of lactate by means of its oxidation in tissues constitutes about 20% of all lactate neutralized in the liver [24]. Many authors find no reliable correlation between concentration of lactate in arterial blood and oxygen debt [23], because artificial increase in lactate in the human body by means of injecting it intravenously leads to insignificant increase in O_2 uptake [24]. Consequently, the causes of neutralization of lactic acid are ambiguous, and they are not consistent with the classical conception of excessive O_2 uptake during the recovery period for faster elimination of lactate.

Gas mixtures with high CO_2 concentration have sometimes been used to stimulate external respiration and restore physical work capacity in man. Brief breathing of air containing 9% CO_2 was used in sports practice to prevent fatigue [4]

and accelerate recovery processes in cortical structures of the brain, which control human motor activity [11]. It is also known that even a slight increase in CO_2 content of inhaled air is associated with diminished exchange of gases, depression of central and peripheral nervous system functions [10], development of respiratory acidosis, which limits human physical work capacity [3, 18]. However, low concentrations of CO_2 in inhaled air accelerate recovery of physical work capacity in athletes in the period between starts [1].

Use for breathing of a mixture containing 1% CO_2 and 35% O_2 was associated in our studies with increase in pulmonary ventilation without change in CO_2 tension in alveolar air, and it was due more to increase in minute volume than in respiration rate. Regulation of gas composition of blood under these conditions was instrumental in accumulation of CO_2, faster restoration of hydrogen ions and parameters of acid-base balance. Intensification of pulmonary ventilation at rest while using gas breathing mixtures containing 1.0-1.5% CO_2 in oxygen, without elevation of p_aCO_2, had been previously reported by many authors [15, 16]. An increase in O_2 content of the gas mixture led to increase in sensitivity of the external respiratory system to low concentrations of CO_2 [2] and increase in circulation by virtue of the vasodilating effect of CO_2 [10].

Physiological reactions that regulate the gas composition of blood can take place as a result of increase in diffusion capacity of the lungs, which determines the kinetics of O_2 and CO_2 through the air-blood barrier [14], as well as retention of endogenous CO_2 in tissues. This is associated with enzymatic activity of carbonic anhydrase and faster synthesis of carbonic acid [9] which, in turn, is dissociated into ions of hydrogen and HCO_3^-. Hydrogen cations form a compound with buffer bases and are eliminated from the body; bicarbonate ions join with sodium chloride and form $NaHCO_3$. According to data in the literature, a 2-fold increase in HCO_3^- concentration causes a 0.3 U increase in blood pH [12].

Thus, the use of gas mixtures enriched with O_2 and CO_2 during the recovery period following intense physical work is a rather effective means of accelerating restoration of acid-base balance in blood.

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UDC: 617-001-02:614.86]:519.86

MATHEMATICAL MODEL OF HUMAN KINEMATIC REACTIONS TO IMPACTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 1 Jul 85) pp 37-41

[Article by I. F. Obraztsov, Yu. G. Konakhevich, V. A. Lyapin, and A. V. Maryin]

[English abstract from source] This paper considers the problem of selecting the structure of a mathematical model that describes the kinematic reactions of the human body during traffic accidents. The paper presents a calculation procedure and a program that allow selection of a structure (up to 17 elements) without deriving repeatedly equations of motion as well as automatic recalculation of all inertia and size parameters.

[Text] The most important conditions for safety against trauma of crew and passengers in vehicles in an emergency situation are to organize the interior of the cabin, design chairs and immobilization systems that would preclude the possibility of impact of the human body with surrounding objects and, at the same time, would provide for comfort and the required range of working movements under ordinary conditions. Obviously, these requirements are mutually contradictory to some extent, and while the methods of ergonomic investigations have been refined rather well at the present time, the study of human body reactions to contact, inertial or aerodynamic impact forces is still a difficult task.

In the last few years, mathematical modeling methods have gained wide use in work on assuring man's safety in traffic accidents, emergency exiting from an aircraft and landing of the latter, as well as other extreme situations. From the practical point of view, models that provide a satisfactory description of the biomechanical aspects of the human body with which we are concerned, with a minimal complexity of software (which, incidentally, also simplifies the task of identifying and certifying models), are preferable. For example, if evaluation of "external" conditions of impact of different segments of the body with surrounding objects is the main element and one can disregard the "internal" stress and deformity of these segments, it is desirable to use so-called "kinematic" models [2, 3], in which anatomic articulations and segments of the human body are represented by joints and undeformable rigid bodies.

The structure of such a model is determined by the anatomical distinctions of the human body, nature of factor to which it is exposed and purposes of a

concrete investigation. For example, the trunk could be described by a set of segments, each of which corresponds to one or several vertebrae with a connected horizontal "section," or else be entirely excluded from consideration ("ideal" immobilization in seat). In the latter case, analysis is made only of kinematics of the head and limbs, and in some situations only the parameters of nodding the head are of interest, so that the extremities are not necessarily taken into consideration in the model. Analogously, in situations where the initial configuration of the body is symmetrical in relation to the sagittal plane and all existing forces are in this plane, one can limit oneself to consideration of the two-dimensional case, etc.

This means that, in practice, the optimum would be to use a set of kinematic models differing in levels of complexity, and it would be desirable to have an algorithm for formulating and solving equations of movements that would permit altering the structure of the model for a concrete task without spending time for repeated formulation of equations. Since classical methods (of Newton, d'Alembert, Lagrange) do not have this property, we used a method here that was described in the monograph of J. Wittemburg [1], which includes use of concepts of graph theory, symbolic matrix and tensor designations.

The structure of the model is described by a graph, the apices of which correspond to bodies of the model and arcs, to joints; mathematically, this structure is set by incidence S matrix. With proper numeration and identically oriented graph arcs, its reciprocal matrix T is set unambiguously. To describe the geometry of the system, mobile base $e^{(i)}$, the beginning of which coincides with the mass center of the ith body and radius-vectors of joint a in base $e^{(i)}$ are related to each body in the system. These radius-vectors $\vec{c}_{ia}$ (i = 1, 2, ..., n; i = 1, ..., n, where n is the number of bodies in the system) equal zero if joint a is not related to the ith body.

Single vectors $\vec{p}_{ai}$ (i = 1, 2, ..., n_a, where n_a is the number of degrees of freedom for the joint) are introduced for each joint, which set the axes of possible angular displacements. These vectors are combined in a quasi-diagonal vector matrix P, which has the following appearance:

$$\vec{P} = \left\| \begin{array}{ccc} \left| \begin{array}{c} \vec{P}_{11} \\ \vdots \\ \vec{P}_{1n_1} \end{array} \right| & \ldots\ldots\ldots\ldots & 0 \\ & \left| \begin{array}{c} \vec{P}_{21} \\ \vdots \\ \vec{P}_{2n_2} \end{array} \right| \ldots\ldots & \\ & & \left| \begin{array}{c} \vec{P}_{n1} \\ \vdots \\ \vec{P}_{nn_n} \end{array} \right| \end{array} \right\| \qquad (1)$$

The matrix has a dimensionality of $n_e \times n$, where n_e is the number of degrees of freedom in the system.

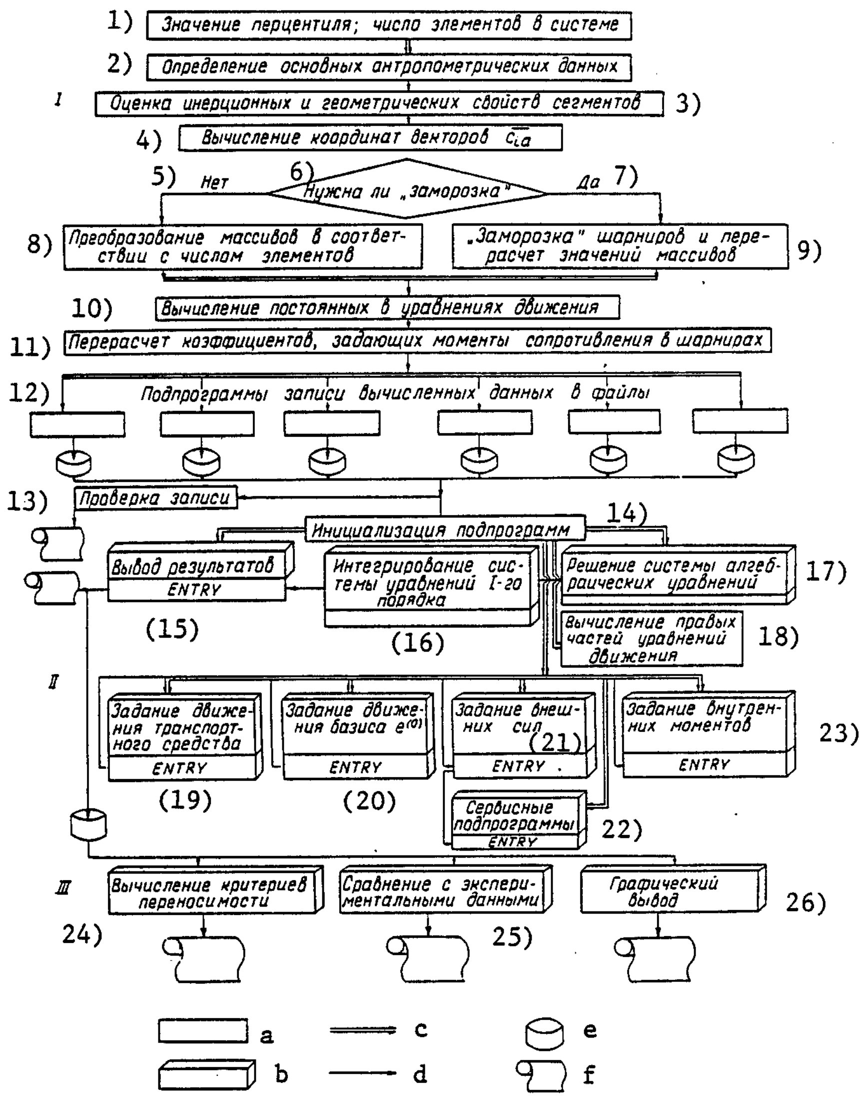

Figure 1. Structure of program complex

I-III) different steps in performance of task
- a) subroutine
- b) set of functionally homogeneous subroutines
- c) access to main input points for initialization
- d) access to subroutine or additional points of ENTRY subroutine when running program
- e) set of data on magnetic disc or tape
- f) output of results on alphanumeric printer or graph plotter
- 1) percentile; number of elements in system
- 2) determination of principal anthropometric data
- 3) evaluation of inertial and geometric properties of segments
- 4) calculation of coordinates of vectors C_{ia}
- 5) no
- 6) is "freezing" needed
- 7) yes

Key to Figure 1, continued:

8) conversion of arrays in accordance with number of elements
9) "freezing" joints and converting array values
10) computation of constants in equations of movement
11) conversion of coefficients specifying moments of resistance in joints
12) subroutines for recording computed data in files
13) checking entries
14) initialization of subroutines
15) output of results
16) integration of 1st-order system of equations
17) solving system of algebraic equations
18) computing right parts of equations of movement
19) setting motion of vehicle
20) setting movement of base $e^{(0)}$
21) setting external forces
22) setting service subroutines
23) setting internal moments
24) computation of criteria of endurance
25) comparison to experimental data
26) graphic output

Finally, matrices are introduced for conversion of G_a:

$$e^{(i^-(a))} = G_a e^{(i^+(a))};\quad a = 1,2\ldots n, \tag{2}$$

which are known functions of generalized coordinates. On this basis, we can construct matrix A_i for conversion of coordinates from base $e^{(i)}$ to base $e^{(0)}$ so that $e^{(0)} = A_i e^{(i)}$ $i = 1, \ldots, n$.

The angular velocity of body $i^-(a)$ in relation to $i^+(a)$ can be written down as:

$$\Omega_a = \sum_{i=1}^{n_a} p_{ai}\dot{\varphi}_{ai};\quad a = 1,2\ldots n, \tag{3}$$

and angular acceleration as:

$$\dot{\Omega}_a = \sum_{i=1}^{n} p_{ai}\ddot{\varphi}_{ai} + \sum_{i=1}^{n_a}\sum_{j=1}^{n_a} \frac{\partial p_{ai}}{\partial \varphi_{ai}} \dot{\varphi}_{ai}\dot{\varphi}_{aj};\quad a = 1,\ldots n. \tag{4}$$

Considering that $\vec{\Omega}_a = \omega_{i^-(a)} - \omega_{i^+(a)}$, $a = 1, \ldots, n$, let us find the angular velocity $\vec{\omega}$ in relation to inertial space:

$$\vec{\omega} = -I^T\vec{\Omega} + \omega_0 1n. \tag{5}$$

Absolute angular acceleration will have the following appearance:

$$\dot{\vec{\omega}} = \dot{\omega}_0 1n - T^T\left(P^T\ddot{\varphi} + \vec{\Omega}_a\vec{\omega}_{i^-(a)} + \sum_{i=1}^{n_a}\sum_{j=1}^{n_a} \frac{\partial p_{ai}}{\partial \varphi_{ai}} \dot{\varphi}_{ai}\dot{\varphi}_{aj} \right). \tag{6}$$

Let principal vector of external forces $\vec{F}_i$ and principal moment $\vec{M}_i$ act upon the ith body in the system. Analogously, there is a principal vector of internal forces $\vec{X}^c$ and principal moment $\vec{Y}$ acting in each joint. Then, Newton's law for successive movement of the ith body will have the following appearance:

$$m_i \ddot{\vec{r}}_i = \vec{F}_i + \sum_{a=1}^{n} S_{ia} \vec{X}_a^c; \quad i = 1, 2 \ldots n, \tag{7}$$

and the equation of moment of number of movements:

$$\dot{\vec{L}}_i = \vec{M}_i + \sum_{a=1}^{n} S_{ia} \left(\vec{C}_{ia} \times \vec{X}_a^c + \vec{Y}_a \right); \quad i = 1, 2 \ldots n, \tag{8}$$

can be rewritten in matrix form:

$$\mathbf{m} \ddot{\vec{\mathbf{r}}} = \vec{\mathbf{F}} + \mathbf{S} \vec{\mathbf{X}}^c; \tag{9}$$

$$\dot{\mathbf{L}} = \vec{\mathbf{M}} + \vec{\mathbf{C}} \times \vec{\mathbf{X}}^c + \mathbf{S} \vec{\mathbf{Y}}. \tag{10}$$

By excluding the force of connection reaction, inserting the value for moment of number of movements and expressing angular velocity and acceleration in generalized coordinates, we shall obtain the equations of movement in their final form:

$$\begin{aligned} \mathbf{A} \ddot{\varphi} &= \mathbf{B}, \\ \mathbf{A} &= (\mathbf{pT}) \cdot \mathbf{K} \cdot (\mathbf{pT})^{\mathrm{T}}; \\ \mathbf{B} &= -(\mathbf{pT}) \cdot [\mathbf{K}(\mathbf{T}^{\mathrm{T}} \mathbf{f} - \dot{\omega}_0 \cdot 1_n) + M' + \\ &\quad + M] - \mathbf{p} \cdot \mathbf{Y}, \end{aligned} \tag{11}$$

where K is the matrix of the system's inertial tensors, f is the matrix of transposable angular accelerations and M' are matrices of induced moments of force.

Then, equation (11) can be solved in relation to generalized coordinates and integrated by one of the Runge-Kutt methods.

This procedure is effected by the program complex that is divided into four sets (for two- and three-dimensional variants of the system, connected or not connected with the external body performing a specified movement). Each set implements the following: at the first stage, computation of constants that are unrelated to time; at the second, integration of equations of movement; at the third (if necessary), calculation of criteria of endurance, comparison to experimental data, graphic rendition of results. These stages are run successively with printing of intermediate results on a magnetic disc. All four sets have the same structure, which is illustrated in Figure 1. Let us note that the program complex provides for automatic conversion of all inertial and dimensional parameters of a kinematic model of any structure, selected on the basis of a basic 17-element variant illustrated in Figure 2.

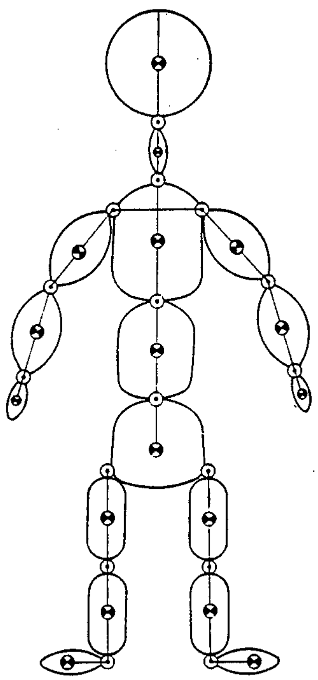

Figure 2.
Basic 17-element kinematic model of the human body

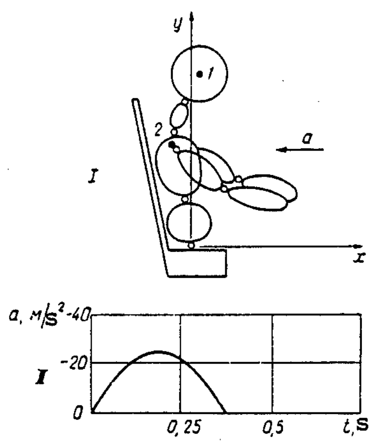

Figure 3.
8-Mass model of human body (I) and acceleration pulse (II) used in calculation

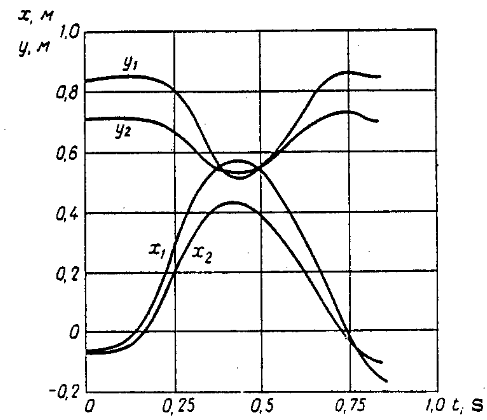

Figure 4.
Change in coordinates of mass center of head (y_1, x_1) and arm point (y_2, x_2) as a function of time for pulse illustrated in Figure 3

Recalculation is done at the first stage and requires setting the anthropometric percentile, number of bodies in the system and numbers of "frozen" joints. The second stage begins with access to the main input points in the subroutines, distribution of memory for all arrays and variables, and connection of subroutines needed for calculations, for example, integration, solving a linear system, setting forces and moments, service subroutines, etc. The obtained values for coordinates (velocities, accelerations), forces and moments are put out on printers and external files.

Service subroutines are used to compute additional parameters, for example, mass centers of segments. The subroutine for internal moments computs resistance to forced movement in joints of the model as a function of time, angles and angular velocities. The subroutine for external forces and moments computes the principal vector and principal moment of external forces for each segment. To calculate contact forces in the interaction of body surface with the seat, belting system, etc., ellipsoids are rigidly tied in to the model bodies, and they simulate the surface of the corresponding segments

of the human body. When such an ellipsoid intersects surrounding surfaces, external resistance forces appear which increase in accordance with the set law with increase in "depth of penetration."

All of the subroutines in the complex are written in the FORTRAN language and are designed for use on EC computers; they are stored in symbol and load libraries on tape. The program complex permits evaluation of kinematic reactions of the human body to impacts lasting 10...1000 ms, and it is a convenient computing tool for the study of the distinctions of such reactions in model experiments.

Although some difficulties arise when put to practical use, which are related to identification of parameters of kinematic models and analytical description of exogenous factors (primarily contact and aerodynamic ones), use of this complex offers some interesting possibilities of estimating the efficacy of various types of equipment to protect man against trauma in emergency situations. Figure 3 illustrates an 8-mass two-dimensional model, which was used to calculate the kinematic reaction of the human body to a horizontal impact acceleration and Figure 4 shows the corresponding results of calculations.

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USE OF CENTRAL ELECTROANALGESIA FOR FUNCTIONAL RECOVERY FROM MOTION SICKNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 5 May 85) pp 42-44

[Article by A. S. Nekhayev, V. D. Vlasov, and V. V. Ivanov]

[English abstract from source] Central electroanalgesia (CEAN) is a technique that involves application of pulsating current to the central nervous system in order to enhance its tonicity recover autonomic equilibrium and to reduce parasympathetic cardiovascular reactions. In two experimental runs in which 9 volunteers participated the efficacy of CEAN in preventing motion sickness symptoms produced by Markaryan's test was studied. After two rotations repeated with a one-hour interval vestibular reactions persisted for 7-10 hours. CEAN had a positive effect: after a one-hour CEAN session applied between two rotations the tolerance time of the second rotation increased on an average by 76%. An additional exposure to CEAN after rotation eliminated almost completely the adverse effects of rotation and made effective the postrotation work. Due to CEAN parasympathetic reactions of the cardiovascular system typical of the postrotation recovery period were indistinct. These data suggest that CEAN is an effective method to be used to help a rapid recovery of the functional state of the human body during motion sickness.

[Text] In a number of instances, the adverse effects of motion sickness can persist for a long time and become the cause of diminished work capacity [9]. Various methods of preventing vestibular disturbances are used extensively, in particular, special screening and vestibular conditioning. Treatment of motion sickness is limited essentially to the use of pharmacological agents, the most effective of which are referable to the group of cholinolytics and antihistamines, which have side-effects [11]. For this reason, the search for new means of preventing and treating motion sickness is an important task for aerospace medicine. Among the methods that help restore impaired autonomic equilibrium, which occurs with marked forms of motion sickness, the method of central electroanalgesia (CEAN) has found application in clinical and sports medicine in recent times [7, 14]. It is interesting to explore the efficacy of CEAN as a potentially promising method of restoring the functional state of the body with development of motion sickness symptoms, which ensues, in particular, from the results of prior studies [15].

Methods

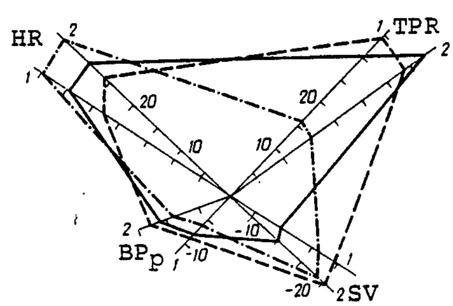
A study was made of 9 essentially healthy subjects 30-45 years of age. Motion sickness was produced by the method of S. S. Markaryan [12]. Vestibulo-vegetative stability was evaluated on the basis of time of test tolerance and expressed as a score [4]. The subjects were exposed twice to angular and Coriolis accelerations within the period of a single investigation, which lasted until marked nausea and retching (control symptom) appeared. Thus, the first round lasted until there was development of marked vestibulo-vegetative manifestations then, after a break (1 h), an analogous round of exposure was repeated. In all there were two series of tests. In the control series, the subjects rested in supine position in the interval between the two rounds of rotation, in the other series CEAN was used during the rest period by means of the Soviet Lenar apparatus that is produced in series. The current used constituted 0.5-0.8 mA with pulse recurrence frequency of 800-950 Hz and duration of 0.15 ms. Split electrodes were placed in the region of the forehead (cathode), under the mastoid process in the neck region (anode) and they were applied on 15-20-layer gauze sponges soaked in 4-5% soda solution [6]. Before and after producing motion sickness, we tested the functional state of the cardiovascular system at rest and during a combined postural test (CPT), which consisted of alternate placement of the subject, twice for 5 min each time, in antiorthostatic [head-down] (tilt angle of -30°) and orthostatic positions (tilt angle +80°). A mingograf-82 instrument of the Siemens-Elema firm (Sweden) was used to record the ECG in the 2d standard lead, tachooscillogram of the brachial artery, sphygmograms of the carotid, radial and femoral arteries. We determined the heart rate (HR) on the basis of 30 RR cycles on the ECG, pulsed arterial pressure (BP_p), stroke volume (SV) and total peripheral resistance (TPR) [16]. In the combined postural test, we estimated the averaged values of parameters over a 5-min period in each position, in relation to the horizontal plane. Reliability of differences was evaluated by means of the criterion of Wilcoxson-Mann-Whitney (U) [5].

Results and Discussion

In the CPT before production of motion sickness (baseline), in orthostatic position, the group presented on the average an increase in HR from 68.3±1.8 to 86.4±1.1/min ($P_U<0.01$), decrease in SV from 72.6±3.1 to 58.3±2.8 mℓ ($P_U<0.01$), increase in TPR from 35.5±1.4 to 47.3±2.2 AU [arbitrary units] ($P_U<0.01$) and drop of BP_p from 46.7±1.5 to 40.4±1.1 mm Hg ($P_U>0.05$). In antiorthostatic position, we failed to demonstrate substantial deviations of parameters from the values recorded in horizontal position, with the exception of SV, which increased from 72.6±3.1 to 84.0±5.1 mℓ ($P_U<0.05$). After rotation, all subjects presented facial pallor, profuse cold perspiration, hypersalivation, severe nausea with retching, vertigo, listlessness and sleepiness. The severity of symptoms of motion sickness was given a mean score of 10.0±0.05 in the control group and 10.6±0.4 in the experimental one, which was indicative of the same intensity of effects. The above symptoms persisted in part in most subjects of the control group for 7-10 h, and in some cases (3 people) vertigo and nausea increased during travel in a vehicle. Tolerance to the test in the second session of rotation increased by a mean of 19.0±3.1%, as compared to the first session, in subjects who did not receive CEAN. They also presented, upon neurological examination, mild tremor of the fingers,

instability in Romberg's position and horizontal nystagmus (neurological monitoring and CEAN method were performed by Yu. N. Bannykh). In the CPT in orthostatic position, there was an increase in HR from 62.5±1.4 to 84.2±1.1/min ($P_U<0.01$), decrease in SV from 64.3±2.9 to 52.5±1.9 mℓ ($P_U<0.01$), increase in TPR from 34.1±1.1 to 40.3±1.4 AU ($P_U<0.05$). BP_p did not undergo appreciable change. Virtually no dynamics were demonstrable in antiorthostatic position.

In the experimental series, autonomic symptoms disappeared entirely after the first session of CEAN. After the second round of rotation and next session of CEAN, the subjects presented an elevated affect, lightness and vigor. In one case there were signs of euphoria associated with increased verbal and motor activity. They worked rather efficiently after the tests, whereas 7 out of 9 subjects in the control group had to apply some effort to work. Tolerance to the CPT test in the second round of rotation, as compared to the first, increased by 76.0±5.3%, which is considerably higher than the result obtained for the control test. During the combined postural test in orthostatic position, we observed increase in HR from 68.2±1.1 to 88.2±1.1/min ($P_U<0.01$), decrease in SV from 68.6±2.1 to 60.0±0.8 mℓ ($P_U<0.05$) and increase in TPR from 37.4±1.1 to 51.0±1.5 AU ($P_U<0.05$). BP_p did not change. No appreciable dynamics were demonstrable in the parameters in antiorthostatic position. The only neurological symptoms were very transient insignificant tremor of the fingers.



Dynamics of cardiovascular system parameters during CPT
Dash line — before rotation, dot-dash line — after rotation, boldface line — after CEAN; 1, 2 — in first and second orthostatic positions, respectively. Deviations of parameters from those recorded in horizontal position are expressed as percentages

After rotation, the subjects developed marked vestibulovegetative symptoms, which persisted in part for a rather long time in most subjects of the control series. The tendency toward bradycardia at rest, which developed in these cases, was indicative of a parasympathetic effect, which is consistent with the clinical signs of motion sickness [1-3, 8, 10, 13, 17]. From the results of the CPT we were able to detect some decrease in functional conservatism of mechanisms of controlling the cardiovascular system, as indicated by the somewhat greater increase in HR and lesser increase in TPR in orthostatic positions (see Figure). Use of CEAN between the two series of rotations increased tolerance to the second one by 57%, as compared to the control group. The second use of CEAN reduced significantly the set of adverse subjective manifestations, and there was no parasympathetic effect in six subjects. We were impressed by the less marked tension of the central component of the mechanism of regulation of the cardiovascular system, as compared to the test performed after rotation without CEAN, which

was characterized by the extent of deviation of HR in orthostatic position, as compared to horizontal. Significant attenuation of vestibulovegetative symptoms after motion sickness may be related to the effect of pulsed current on the central nervous system, which generated an area of cathodic depression within the frontal regions and reduced significantly perception of impulsation from the periphery, as well as changed the functional associations of the frontal cortex with, primarily, the hypothalamus [7, 14]. It can be assumed that CEAN provides beneficial conditions for the central nervous system to adapt to stress factors, which also include the vestibular stimuli that lead to development of motion sickness.

Thus, additional information was obtained about the possibility of using CEAN as a means of preventing and treating motion sickness. Agreement of our results with the data in [15] is indicative of existence of an objective pattern that determines the desirability of continuing observations in this direction. Still unclear is the choice of CEAN modes as related to individual tolerance and severity of symptoms of motion sickness.

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UDC: 629.78.048:[613.2:612.398

BIOLOGICAL VALUE OF PROTEINS IN FOOD ALLOWANCE OF SALYUT ORBITAL STATION CREWS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 15 Oct 84) pp 44-48

[Article by V. P. Bychkov, T. F. Vlasova, V. N. Gryaznova, Ye. A. Sedova, A. K. Sivuk, V. A. Tretyakova, and A. S. Ushakov]

[English abstract from source] The biological value of the protein component of three modifications of the Salyut space diet was measured in laboratory studies and in simulated space flights. Three experimental runs of up to 68 days in duration were carried out on 20 volunteers. During the study the following parameters of protein metabolism were measured: total protein and protein fractions in serum; urea, uric acid and creatinine in blood; total nitrogen, urea, ammonia, uric acid and creatinine in urine. The results obtained showed that the diet modifications provided an adequate nutritional status and a normal level of the above parameters of protein metabolism.

[Text] The guidelines for supplying the food in life-support systems (LSS) of spacecraft depend on both the duration of missions and structural distinctions of the LSS as a whole [4]. With increase in duration of missions, it is more desirable to use dehydrated (freeze-dried) products, since this would reduce the weight of supplies at launching time if there are means of regenerating water on board.

The desirability of including foods dehydrated by the freeze-drying method in the food allowances of cosmonauts was validated previously [2-4].

One of the important issues in cosmonaut nutrition is to furnish a sufficient amount of first-class protein. In this study, we evaluated the adequacy of the protein component of food allowances consisting of different combinations of dehydrated foods and products preserved by other methods, to the human requirements in long-term spaceflights.

Methods

In order to determine the biological value of the protein component of the food allowances, we conducted 3 series of tests with the participation of 20 male subjects who were kept on these diets for a long time (up to 68 days).

In the course of the studies, we determined the following parameters of protein metabolism: blood serum total protein and its fraction, blood plasma free amino acids, urine total nitrogen, urea, ammonia, uric acid and creatinine. In the 3d series, urea, uric acid and creatinine were also assayed in serum [1].

In the 1st series, which involved 10 subjects, we tested the biological value of proteins contained in the foods of a diet consisting of a combination of dehydrated (15%) products and those preserved by other methods (85%). The diet that was used for 60 days contained 141 g protein, 94 g fat, 346 g carbohydrates, 0.7 g calcium, 1.7 g phosphorus, 0.4 g magnesium, 2.8 g potassium and 4.2 g sodium, totaling 12,375 kJ (2880 kcalories) per day. All of the essential nutrients were present in sufficient amounts and well-balanced proportion. The subjects were kept on the diet under laboratory conditions maintaining their customary schedule.

In the 2d series of studies, which lasted 68 days, there were 5 participants (1 only in the baseline period). The baseline period lasted 20 days, experimental period 42 days and recovery period 6 days. During the experimental period the subjects remained in a small pressure chamber. Starting on the 6th day, an ammonia concentration of ~2 mg/m^3 was maintained in its atmosphere. The diet included considerably more freeze-dried foods than in the 1st series (up to 65% of total caloric value). The diet was prepared on a 6-day menu plan with 4 meals per day, and it contained the following: 159 g protein, 131 g fat, 396 g carbohydrates, 0.9 g calcium, 2.5 g phosphorus, 0.5 g magnesium, 3.8 g potassium and 6.1 g sodium, totaling 13,807 kJ (3300 kcalories) per day.

In the 3d series, we studied the biological value of the protein component of a diet made up with consideration of data obtained from prior studies. This version of the diet was enriched with a number of nutrients (glucose, phosphatide concentrate, vitamins, minerals), the normalizing effect of which on metabolism in the presence of nervous and emotional tension had been established in our 1st series of tests. In addition, this diet, which consisted mainly of dehydrated foods, contained dishes prepared from natural products and preserved by the deep-freeze method. The mealtime schedule was the same as in the first two series. In this series, 6 men consumed the tested diet for 16 days under ordinary living conditions (baseline), 14 days of antiorthostatic (-8°) hypokinesia (HDT [head-down tilt]) and 26 days of the recovery period. Total duration of the study was 58 days. The diet contained the following amounts of basic nutrients: 152 g protein, 133 g fat, 420 g carbohydrates, 1.1 g calcium, 2.3 g phosphorus, 0.4 g magnesium, 4.6 g potassium and 6.0 g sodium, totaling 14,225 kJ (3400 kcal) per day.

Results and Discussion

In the 1st series of tests, the subjects retained a normal protein metabolism throughout the observation period. Their weight showed virtually no change, nitrogen equilibrium was maintained, or else there was a positive nitrogen balance.

Within the limits of this study, we tested several nutrients aimed at prevention of metabolic disturbances (including those referable to protein metabolism),

which occur with exposure to factors that elicit nervous and emotional tension. The results of this investigation were described in greater detail previously [5-7].

In the 2d series of studies, most subjects had a good appetite and they consumed virtually all of their food allowance. There was rather high assimilation of protein (87%). Considering the amount of food consumed and assimilation of proteins, the subjects intake per day averaged 131 g protein outside the pressure chamber and 107 g in the chamber. Only 1 subject, who weighed about 20 kg more than his ideal weight, lost 5.5 kg.

There were no reliable deviations in composition of serum protein fractions, in relation to the baseline, throughout the observation period. Serum total protein also failed to undergo reliable changes (7.67±0.31 g% in the baseline period, 8.00±0.2 g% in the pressure chamber and 7.45±0.24 g% in the recovery period).

Plasma concentrations of free amino acids were in the range of the physiological norm and did not undergo reliable changes at different phases of the study.

The results of assaying excretion of end products of nitrogen metabolism in urine (Table 1) indicate that they remained within the physiological range throughout the period of the study. Their fluctuations at different stages of the study are apparently related to change in correlation between catabolic and anabolic processes in the subjects.

Table 1. Excretion in urine of end products of nitrogen metabolism (g/day) in subjects of 2d series of studies (M±m)

Parameter	Baseline	Days in press. chamber		Recovery period
		1-5	6-42	
Total nitrogen	18,4±0,34	17,2±1,72	15,4±1,63	16,9±1,67
Urea	31,7±0,83	28,7±3,03	25,7±2,72	27,2±1,98
Ammonia	1,07±0,03	0,96±0,09	1,04±0,12	1,44±0,08
Creatinine	1,99±0,03	1,50±0,16	1,62±0,16	1,86±0,23
Uric acid	1,12±0,03	0,75±0,08	0,92±0,11	1,04±0,11

Nitrogen balance was positive in the baseline and recovery periods (+1.1 and +2.6 g, respectively) and close to zero in the pressure chamber.

Thus, the results of the 2d series of studies revealed that the tested diet was instrumental in preserving a normal protein metabolism in 5 subjects under ordinary living conditions and in 4 who spent 42 days in the pressure chamber.

In the 3d series, the subjects retained a good appetite, they experienced a normal feeling of satiation, there were no dyspeptic disorders and weight fluctuations were insignificant. Considering assimilability of protein, which

constituted about 92%, as well as actual amount of food taken, the subjects' average intake of assimilable proteins constituted 124 g before and after HDT and 106 g/day during HDT.

In the baseline period, there was retention of a normal level of urea, creatinine and uric acid in the subjects' serum. During HDT there was some increase in concentration of urea on the 21st day (7th day of HDT) and decrease in concentration of creatinine on the 21st and 28th days of the study (7th and 14th days of HDT), which was apparently attributable to diminished motor activity. On the 26th and 28th days (12th and 14th days of HDT) there was some increase in concentration of uric acid in serum. The recovery period (32d and 40th days of the study) was characterized by normalization of the tested parameters. The increase in concentration of creatinine and decline of uric acid level on the 56th day was apparently due to nervous and emotional tension related to the end of the study.

Table 2. Protein spectrum (g%) of subjects' blood serum in 3d series of studies (M±m)

Parameter	Baseline	HDT	Recovery period
Total protein	8,25±0,19	7,49±0,16*	7,96±0,09
Albumins	4,75±0,12	4,31±0,07*	4,39±0,08**
Postalbumins, fast	0,22±0,01	0,22±0,02	0,27±0,01***
Postalbumins, medium	0,09±0,01	0,07±0,01	0,13±0,01*
Postalbumins, slow	0,09±0,01	0,06±0,01	0,10±0,01
Transferrin	0,79±0,14	0,64±0,11	0,73±0,30
Complementary globulins	0,18±0,01	0,13±0,004*4	0,15±0,01
Posttransferrins, fast	0,14±0,01	0,11±0,01	0,16±0,01
Posttransferrins, slow	0,29±0,03	0,28±0,02	0,22±0,02
Immunoglobulins	1,45±0,04	1,02±0,07*4	0,68±0,03*4
Macroglobulins	0,24±0,02	0,64±0,03*4	1,17±0,07*4

* $P < 0,02$.
** $P < 0,05$.
*** $P < 0,01$.
*4 $P < 0,001$.

In the experimental period, there was some decrease in serum total protein content (P<0.02) due to decrease in its concentration in the fractions of albumin (P<0.02), complementary globulins (P<0.001) and immunoglobulins (P<0.001) (Table 2). These changes did not exceed the physiological range, and they were apparently related to decline of anabolic processes in the body. The concurrent increase in protein concentration in the macroglobulin fraction (P<0.001) did not affect the general tendency toward decrease in serum protein content. The distribution of protein in fractions after HDT was analogous to the baseline status.

The change in free amino acids of plasma (Table 3), as well as total nitrogen, urea, uric acid and creatinine in urine (Table 4) did not exceed the range of conventional norms throughout the study in most cases. After HDT, there was a decrease in plasma concentration of methionine, aspartic and glutamic acids.

Nitrogen balance was positive before and after HDT (+1.7 and +3.7 g, respectively) and close to zero during HDT. The fluctuations observed at different stages in the tested parameters were apparently adaptive to the prevailing conditions.

Table 3. Plasma free amino acid content (mg%) in 3d series of studies (M±m)

Parameter	Baseline	HDT (13th day)	Recovery per. (25th day)
Isoleucine	0,84±0,12	0,69±0,04	0,87±0,11
Leucine	1,34±0,31	1,49±0,05	1,43±0,10
Valine	2,32±0,40	2,07±0,30	2,47±0,17
Threonine	0,75±0,14	1,05±0,07	1,14±0,13
Serine	3,63±0,31	3,68±0,45	3,64±0,21
Methionine	0,36±0,08	0,28±0,02*	0,32±0,03
Tyrosine	1,43±0,21	0,81±0,02	1,10±0,14
Phenylalanine	1,32±0,18	1,05±0,17	1,26±0,19
Cystine	1,55±0,31	0,74±0,27	1,61±0,37
Aspartic acid with asparagine	1,17±0,20	0,61±0,07*	1,09±0,05
Glutamic acid with glutamine	2,97±0,46	1,94±0,15*	3,04±0,34
Proline	1,95±0,30	1,39±0,05	1,99±0,17
Glycine	1,76±0,27	1,74±0,22	1,87±0,21
Alanine	2,60±0,34	2,18±0,09	2,74±0,18
Lysine	2,25±0,08	1,88±0,20	1,97±0,09
Histidine	1,23±0,21	0,96±0,02	1,19±0,11
Arginine	0,83±0,15	0,97±0,06	1,41±0,07
Total amino acids	28,30	23,53	29,14

* $P < 0,05$.

Table 4. Excretion of end products (g/day) of nitrogen metabolism in 3d series of studies (M±m)

Parameter	Baseline	HDT	Recovery period
Total nitrogen	16,8±0,81	15,8±0,80	15,4±0,75
Urea	32,3±4,59	28,2±2,02	30,2±2,89
Ammonia	0,87±0,05	1,07±0,12	1,23±0,21
Uric acid	0,99±0,61	1,17±0,10	1,29±0,20
Creatinine	1,22±0,06	1,37±0,06	1,12±0,13

The data obtained in the 3d series of studies are indicative of quantitative and qualitative conformity of the protein component of the tested diet to the subjects' requirements.

To sum up these investigations, it can be concluded that the tested versions of diets maintained a satisfactory nutritional status and normal levels of tested parameters of protein metabolism in all subjects, under both ordinary living conditions and with simulation of weightlessness (HDT), which enables us to recommend them as sources of first-class protein.

Considering the fact that, in the 3d series of studies, there was a more diversified assortment of foods in the diet and it contained additional nutrients that have a corrective effect on protein metabolism in the presence of nervous and emotional tension, preference should be given to expressly this variant as a source of protein.

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UDC: 612.766.2.014.47-08:612.111.3.014.46:
615.356:577.164.64/.17

EFFECT OF COAMIDE AND FOLICOBALAMIN ON ERYTHROPOIESIS UNDER NORMAL LIVING CONDITIONS AND DURING ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 19 Jun 85) pp 48-53

[Article by R. K. Kiselev, A. M. Chayka, and V. I. Legenkov]

[English abstract from source] The study was performed on 41 healthy men, aged 19 to 40, who led a normal life or were exposed to short-term or long-term head-down tilts. The effectiveness of hemostimulants was determined with respect to hemoglobin, red blood cells or reticulocyte counts. Folicobalamine and coamide administration in therapeutic doses increased hemoglobin and reticulocyte blood levels in the ambulant subjects or those exposed to a 7-day head-down tilt. The effect was stable and persisted for 2-3 weeks after which the blood parameters returned to the pretest level. Folicobalamine administered at the final stage of 50-day head-down tilt facilitated partial recovery of hemoglobin during the study (which is very important) and rapid recovery after it. The objective and subjective tolerance of the drugs was good. It is therefore concluded that folicobalamine should be taken at the final stage of head-down tilt or spaceflight to alleviate readaptation to the normal environment.

[Text] Man's exposure to weightlessness has an appreciable effect on blood and fluid-electrolyte metabolism [2, 4, 6, 8]. According to the data of Soviet and foreign researchers, cosmonauts who have flown for over 2 weeks present a decrease in both erythrocyte mass and hemoglobin. In Soviet cosmonauts who participated in flights lasting 7 to 211 days, there was a decrease by an average of 15-20% in hemoglobin mass and occasionally (49- and 75-day missions) to 30% of the base value; during the same missions, there was a decrease in reticulocyte count, from 27 to 54% [3, 4, 7]. According to data of American researchers [9, 10], the decrease in astronauts' erythrocyte mass was somewhat less marked, constituting a mean of 10-15%, during missions on the Gemini, Apollo and Skylab programs.

Some foreign authors [11] expounded a hypothesis, on the basis of estimates, that synthesis of hemoglobin, which was impaired at the start of a flight, should revert to the base level after 100 days in space. However, the facts

we obtained indicate that such compensation does not occur [4, 7]. The decrease in hemoglobin progresses with increase in flight duration to 2-2.5 months, and this is followed by some slowing of decline, but still the hemoglobin deficiency constituted 17.1% of the baseline in the case of a 175-185-day flight and 23.4% in a 211-day day flight.

The observed changes in the red blood system were called by researchers the "erythrocytopenic syndrome of weightlessness" [7], and they became the object of close scrutiny.

The hemoglobin deficiency after long-term flights is specific for this state, at any rate it is considerably greater than in most patients suffering from serious nonhematological diseases who require hospital care. For this reason, the need arises to develop the means of preventing hemopoietic disturbances in weightlessness and of shortening postflight recovery time.

Among the many groups of substances that enhance erythropoiesis, there are two groups of pharmacological agents that are of the most interest: cobalt preparations which have the properties of erythropoietin and vitamins (vitamin B_{12} and folic acid), which stimulate different aspects of protein metabolism [5]. The anemia-controlling action of folicobalamin, which contains vitamin B_{12} and folic acid, has been well-documented for certain types of pathology due to a shortage of these nutrients. However, we still do not know whether it is effective in healthy people whose nutrition is satisfactory. The same applies (though to a lesser extent) to cobalt preparations.

Methods

This study was conducted on 41 healthy men 19 to 40 years of age, whose activities were not restricted and who continued to perform their jobs, as well as under conditions of brief and long-term antiorthostatic hypokinesia (HDT [head-down tilt]). Brief HDT was used at -6° angle for 7 days; long-term HDT was used for 50 days at an angle of -6° and 120 days at an angle of -4.5°. The subjects were under observation for 1.5 months of a recovery period. Table 1 lists the experimental conditions and agents used. Some of the subjects were on a diet that was similar in composition to the flight diet, others ate at home and average caloric value of the food allowance was about 4000 kcalories. Cobalt preparations--1% coamide for intramuscular injection--and a group B_{12} agent--folicobalamin in tablet form,each tablet containing 0.05 mg vitamin B_{12} and 5.0 mg folic acid--were used as blood stimulants. The daily intake of folicobalamin was in a dosage that exceeded by 8 times the daily requirements for these vitamins.

The efficacy of these agents was assessed by means of measuring total hemoglobin by the carbon monoxide method [1], concentration of hemoglobin and red blood cell and erythrocyte counts by conventional clinical methods.

Results and Discussion

In series I, II and III studies, we determined the effect of blood stimulants on healthy man under ordinary living conditions. The changes in hematological parameters are listed in Table 2. We found that 7-day intake of coamide and

10-day intake of folicobalamin, as well as combined intake of these agents, elicited stimulation of hemopoiesis, which was reflected in the tested parameters. Hemoglobin mass increased by a mean of 5-7%, as compared to the baseline with both separate and combined intake of the products. Maximum increase was observed about 2-3 weeks from start of intake and it persisted for up to 1.5 months.

Table 1. Test conditions in different series

Series of studies	Numb. of subjects	Conditions	Agent intake, days	Observation time, days	Coamide (1000 mg/day)	Vit.B_{12} (15 μg/day)	Folic acid (15 μg/day)
I	5	Unrestricted	7	40	+	—	—
II	8	"	10	40	—	+	+
III	4	"	10	40	+	+	+
IV	3	HDT, 7-days	7	50	—	+	+
V	5	" " "	7	50	+	—	—
VI	4	" " "	7	20		Placebo	
VII	6	HDT, 50 days	14	80	—	+	+
VIII	6	HDT, 120 "	—	150		Control	

Table 2. Effect of erythropoiesis stimulators on hematological parameters with unrestricted living conditions (X±m)

Parameter	Series	Agent	No of sub.	Baseline	Days after start of intake: 16	22	30-33	40-42
Hb mass, g	III	FC+CO	4	724±7	758±5**	762±5**	743±7	752±6*
	II	FC	8	719±10	777±6**	756±10*	754±8*	748±8*
	I	CO	5	715±4	756±13**	—	—	758±5*
Hb concentration, g/ℓ	III	FC+CO	4	154±3	153±3	151±4	136±1	153±2
	II	FC	8	146±3	140±2	137±9*	139±4	146±3
	I	CO	5	151±3	150±1	—	—	—
Reticulocytes, thou/mm^3	III	FC+CO	4	23,6±1,6	22,7±2,5	24,3±2,6	26,9±0,6	23,9±1,9
	II	FC	8	22,8±1,2	24,9±0,6	23,3±1,1	25,1±0,6	19,5±2,8
Red cells, million/mm^3	III	FC+CO	4	4,89±0,07	4,59±0,16	4,57±0,25	4,68±0,22	4,41±0,38
	II	FC	8	4,50±0,13	4,78±0,09	4,63±0,09	3,86±0,29*	3,61±0,13**

Note: Here and in Table 3, FC--folicobalamin, CO--coamide; one asterisk--$P<0.05$, two--$P<0.01$.

By the end of the first month of product intake, peripheral blood showed a 12-15% increase in reticulocyte count, as compared to the baseline, which is indicative of intensification of bone marrow hemopoiesis. Erythrocyte count and hemoglobin held at the base level with insignificant fluctuations, which is

indicative of absence of blood clotting. This is probably related to the fact that, along with increase in hemoglobin, there is increase in liquid part of blood. Subjectively, intake of the agents was well-tolerated.

Since intake of these agents in the indicated dosage has a stimulating effect on hemopoiesis in healthy people, a study was made of their effect in the case of 7-day HDT. As shown previously [4], at the early stages of HDT there is clotting of blood and decrease in reticulocyte by the 3d-4th day, which is apparently the triggering mechanism for depression of erythropoiesis. It was interesting to see how these hemopoiesis stimulators would act in the presence of such changes in the red blood system: would it be possible to correct the changes in hemoglobin concentration and reticulocyte count, or at least to reduce them? The results of these studies are listed in Table 3.

Table 3. Effect of erythropoiesis stimulators on hematological parameters during 7-day HDT (X±m)

Parameter	Series	Agent	Number of subjects	Baseline	Day of HDT		Day of recovery			
					3	7	3	7	14	42
Hb mass, g	IV	FC	3	747±2	—	759±5	—	774±13*	763±18	741±10
	V	CO	5	748±6	—	770±8	—	781±10*	772±4*	743±11
	VI	Pl	4	748±4	—	751±5	—	—	746±5	—
Hb concentration, g/ℓ	IV	FC	3	152±5	169±9	158±6	139±8	—	—	—
	V	CO	5	155±5	165±7	167±3	145±6	147±7	113±13	—
	VI	Pl	4	151±3	166±5	162±3	—	—	148±5	—
Reticulocytes, thous/mm^3	IV	FC	3	28.0±3.8	16.0±3.9**	18.2±2.2**	18.7±2.3**	—	27.0±1.1	—
	V	CO	5	28.8±1.6	12.9±2.0**	18.8±2.3**	21.4±1.0**	—	23.7±3.0*	—
	VI	Pl	4	29.3±1.5	15.2±1.9**	19.9±1.3**	—	—	21.3±2.4*	
Red cells, million/mm^3	IV	FC	3	5.34±0.60	4.69±0.10	4.34±0.13	4.97±0.19	—	4.97±0.27	—
	V	CO	5	4.89±0.30	5.13±0.14	4.58±0.33	4.52±0.16	—	4.50±0.30	
	VI	Pl	4	4.84±0.11	4.36±0.05	4.64±0.05	4.09±0.06	—	4.49±0.25	

Note: Pl--placebo; here and in Table 4, one asterisk--P<0.05, two--P<0.001.

Analysis of the obtained data shows that folicobalamin and coamide had some stimulating effect even during brief (7-day) HDT. The effect was somewhat less marked than with intake of these agents under ordinary living conditions. Hemoglobin mass increased reliably by 5% by the 7th-14th days of the recovery period, as compared to the base value. Hemoglobin concentration in peripheral blood is indicative of clotting at the early stage of HDT. Peripheral blood reticulocyte count dropped in all three studies at the early stage of HDT, and the extent of the drop was the same. After HDT and intake of stimulating agents in series IV and V, we observed 48 and 26% increase, respectively, in reticulocyte count, which is indicative of more intense bone marrow hemopoiesis. In spite of the increase in hemoglobin mass in the recovery period, we failed to demonstrate changes in blood concentration, i.e., the body retained fluid in the vascular system in order to maintain optimum concentrations. In assessing the change in hematological parameters with intake of stimulating agents during 7-day HDT, it should be noted that their intake in

the selected dosage did not eliminate entirely the effect of the mechanisms that inhibit erythropoiesis at the early stage of HDT.

After we obtained proof that the hemopoiesis stimulators have a beneficial effect on erythropoiesis during 7-day HDT, we tried to test their effect in the case of long-term HDT. For this purpose, we tested the stimulating effect of an agent taken 2 weeks before the end of the study. This period corresponded to maximum increase in hemoglobin mass in the preceding series of studies. Intake of the preparations should have stimulated the bone marrow, raising it to a higher level of hemoglobin synthesis and prepared the body for the post-HDT recovery period. In this study (series VII), we used folicobalamin, since no appreciable differences were found between the effects of coamide and folicobalamin, and the latter had the advantage of being taken by mouth. The agent was taken for 14 days to elicit a more marked effect. HDT (-4.5°, series VIII) for 120 days served as control for this study during which no preventive agents were used.

Table 4. Effect of FC on hematological parameters during long-term HDT (X±m)

Testing time	50-day HDT			120-day HDT		
	Hb mass, g	Hb concentr. g/ℓ	red cells, million/ mm^3	Hb mass, g	Hb concentr. g/ℓ	red cells, million/ mm^3
Baseline	712±10	151±2,0	4,42±0,08	755±11	138±7,0	3,85±0,07
Day of HDT:						
3	—	173±3*	3,81±0,80	—	153±4,7**	4,19±0,12
5	—	175±1,4*	4,68±0,16	—	152±4,0**	4,25±0,18
20	634±8*	165±2,0**	4,63±0,08	680±10*	143±5,0	4,20±0,17
30	604±9*	159±2,0	4,35±0,09	650±10*	140±4,0	4,09±0,16
Intake of agent from 31st to 42d days						
36	576±8*	158±3,0	3,96±0,13**	—	—	—
42	616±10*	160±3,0	4,20±0,14	624±11*	147±4,6	4,56±0,14*
49	638±7*	161±3,0	4,10±0,10	—	—	—
85	—	—	—	552±12*	138±3,0	4,30±0,12**
110	—	—	—	533±13*	141±3,0	4,61±0,14*
Recovery period, day: 30	722±9	148±2,0	3,60±0,10*	647±25**	148±4,0	3,83±0,25

Table 4 lists the results of these studies. In both series (VII and VIII), we first observed an increase in hemoglobin concentration and erythrocyte count due to discharge of fluid from the vascular system. Against this background, hemoglobin mass decreased by 15.2 and 14.0% in the 7th and 8th series, respectively, by the 30th day, as compared to the baseline, and it is from this time that folicobalamin began to be taken in series VII at the rate of 1 tablet 3 times a day, after meals. With intake of this agent, hemoglobin mass continued to decline and, by the 36th day, it had dropped to 19%; at the time intake was discontinued (42d day) there was an increase in Hb mass, and by the end of the study (49th day) the shortage decreased by one-half, i.e., it constituted 9.5%. This process occurred in the presence of insignificant fluctuation of Hb concentration and decrease in erythrocyte count due to fluid retention in vessels. Complete restoration of Hb mass in series VII was observed by the 30th day of the recovery period, with normal concentration of hemoglobin and diminished red cell count. Hb deficit of 18-20% after 30-day

hypokinesia and actual spaceflights was usually corrected within 1.5-2 months of recovery, as indicated previously [4]. In the control series VIII, hemoglobin mass diminished to the end of the study and, by the 110th day, the deficit constituted a mean of 29.4%. By the 30th day of the recovery period, Hb mass was still reliably lower than baseline values in series VIII.

Thus, the use of folicobalamin during 50-day HDT in the proposed dosage was instrumental in partial restoration of Hb mass even during the study and (which is very important) speedy restoration in the recovery period. As in the preceding series, excessive production of hemoglobin and significant clotting of blood did not occur during or after HDT, i.e., there was moderate stimulation of bone marrow hemopoiesis. The subjects presented no complaints or undesirable side-effects from taking this agent.

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UDC: 612.591-08:612.79.014.49

HUMAN TOLERANCE TO HIGH-INTENSITY CONTACT HEAT ON INTEGUMENTAL SURFACE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 30 Jul 85) pp 53-55

[Article by A. P. Kozlovskiy and Ye. A. Lushchikov]

[English abstract from source] Significant heating of the thermoprotective suit leads to a rapid growth of the temperature of its inner layer which is in contact with the human body. Prediction of the allowable time of high-temperature exposure is important when evaluating safety parameters. This paper presents the results of measuring the time during which the direct contact between cotton and wool clothes and the forearm skin can be tolerated. The results describe the time and amplitude parameters of the maximally allowable heat exposure. They can be used in testing prototypes of the protective equipment and in selecting their thermophysical characteristics as applied to an extreme environment.

[Text] High temperature causes heating of insulated gear and penetration of heat flux to the human body. The temperature gradient is determined by the thermophysical properties of the fabric in the gear. Their optimum choice is based on limiting the time and amplitude parameters of internal layer temperature at certain pressure levels in the area of contact, site and area heated. Maximum tolerated parameters, in turn, depend on general patterns and individual tolerance of man to this factor.

In the literature there has been in-depth discussion of the question of choice of criteria of tolerance to heat. It is believed that unbearable pain is the integral indicator of heating of the integument to the point of appearance of early signs of denaturation and first-degree burn [6]. Studies of tolerance to emitted heat are of definite interest [1-5]. Their findings can be interpreted, making some assumptions, as applied to the effect of contact temperatures in a specific situation. Our objective here was to determine the time and amplitude parameters of a heat factor that correspond to the limit of tolerance to contact with heated surfaces.

Methods

This study was conducted on 22 men 26 to 45 years old. The unprotected internal surface of the forearm was exposed to heat, due to the high sensitivity of this

part of the skin. Thus, there was guaranteed extrapolation of data on localization of exposure without risk of exceeding thresholds.

The model of a heat factor was produced by means of an oven in which a duralumin base was placed, in the form of a rectangular parallelepiped heated to a stable distribution of temperatures. The contact surface, $1.6 \cdot 10^{-3}$ m^2 in size, was covered with the material from the inside layer of protective gear. Since the gear is worn under actual conditions over ordinary clothing or underwear, we used cotton (c) or all-wool (a/w) fabric with the thermophysical properties listed in the Table. Since worsening of tolerance to heat is associated with elevation of pressure in the region of contact, we limited it in our studies to $(0.5 \pm 0.1) \cdot 10^5$ N/m^2, which corresponds to the force of pressing on heated surfaces when working under extreme conditions. The temperature of the base was recorded as a function of time with a chromel-copel thermocouple situated within the base on the side of the contact surface.

Thermophysical properties of tested fabrics

Parameters	cotton	wool
Thickness, m	0,0006	0,0007
Specific heat, J/kg•degree	1680	1680
Thermal conductivity, W/M•degree	0,00932	0,00349
Density, kg/m^3	244	142

The subject inserted his forearm, exposed on its internal aspect, in the oven through a special opening and kept it tight against the contact surface. The hand and external aspect of the forearm were protected with insulated shields to preclude the effect of radiated heat from the walls of the oven. Onset of unbearable pain served as the criterion of limit of tolerance to heat.

We conducted 182 tests in all, in 110 of which we determined the limit of tolerance to contact with heated cotton fabric and in 72, to wool fabric.

Results and Discussion

The primary data for each subject consisted of 4-6 points with coordinates of temperature and exposure time corresponding to tolerance range. From these points, individual tolerance curves were plotted: 22 for contact with cotton material and 18 with wool. This approach enabled us to subsequently use pro-stochastic analysis as related to concrete values of the argument (exposure time) in accordance with the tolerance curve for each subject. The probability curves of range of tolerance according to temperature of contact surface as a function of different exposure times are illustrated in Figure 1.

Equally probable (P = 0.05) curves were plotted from the data in Figure 1 in order to determine the probability of range of tolerance in a continuous series of time parameters (Figure 2). The illustrated curves correspond to a 5% probability of tolerance range. Analogously, we could submit curves for any given probability as a function of the risk taken.

As a result of this work, it was possible not only to assess the efficacy of existing means of protection against heat, but to predict the probability of

reaching the limit of tolerance with use of a potential type of protective gear according to the results of engineering tests.

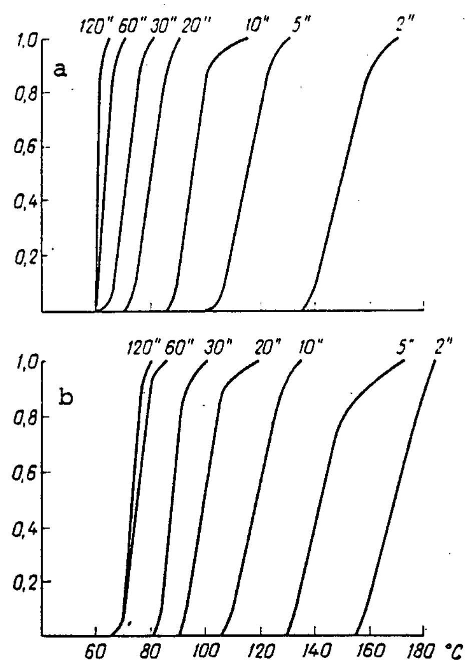

Figure 1.
Probability of onset of unbearable pain upon contact with cotton (a) and woold (b) fabric as a function of exposure time. X-axis, contact temperature; y-axis, probability of onset of unbearable pain

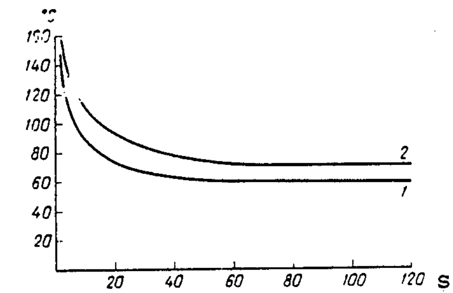

Figure 2.
Curves of equal probability (P = 0.05) of range of tolerance to contact temperatures. X-axis, contact time; y-axis, contact temperature
1, 2) cotton and wool fabrics, respectively

However, in designing gear one generally uses parameters of heat flow, which reflect the process of heat transfer, regardless of thermophysical properties of the contact surface, force of pressure, etc. The obtained data permit such conversions if certain assumptions are made.

Considering the fact that approximately constant temperature levels are established on the external surfaces of fabric adhering to the base and skin of the forearm, and that the thickness of the fabric is small, the penetrating heat flow can be calculated using the formula for stationary heat conductivity:

$$q = \frac{T_b - T_s}{\delta_T} \cdot \lambda_T$$

where T_b is temperature of base, T_s is temperature of integument at limit of tolerance (45°C), λ_T is fabric thermal conductivity and δ_T is thickness of the fabric.

Estimated density of heat flow corresponding to different contact temperatures is illustrated in Figure 3. A comparison of these estimates to data in the literature [1-5] indicates that the critical values for heat flow are similar.

Thus, it can be concluded that the thermophysical model we discussed is adequate for the study of tolerance to brief high-intensity heat on the surface of the human body, and they can be used in testing prototypes of protective gear, as well as to select its thermophysical characteristics as related to expected work under extreme conditions.

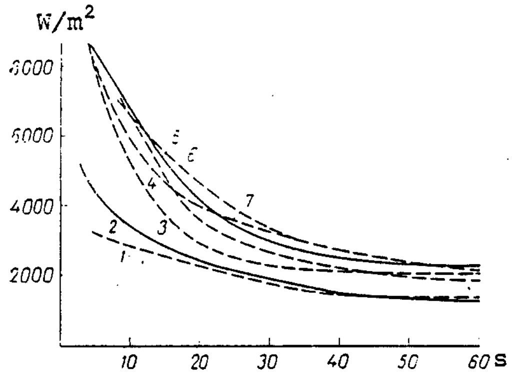

Figure 3.
Range of tolerance to flow of heat; x-axis, contact time; y-axis, density of heat flow
1) data of N. F. Galanin [1]
2) our data for cotton fabric (P = 0.05)
3) data of P. Webb [4]
4) data of G. Kh. Shakhbazyan [5]
5) our data for wool (P = 0.05)
6) data of L. Ya. Ukvolberg and Z. A. Yashumova [3]
7) data of I. I. Dedenko et al. [2]

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UDC: 629.78:612.821.33/.35-019-08

BEHAVIORAL REACTIONS OF ANIMALS EXPOSED TO SPACEFLIGHT CONDITIONS IN THE PRENATAL PERIOD

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 12 May 85) pp 55-60

[Article by Z. I. Apanasenko, M. A. Kuznetsova, and V. Yu. Korotkova]

[English abstract from source] The Wistar female rats were flown on the biosatellite Cosmos-1514 during their pregnancy days 13-18. Offspring (at the age 1 to 3 months) of four of these rats were used to investigate their behavioral reactions in the open field and mazes of different design, food attraction being applied. Control rats of matched pregnancy term were kept either in a vivarium or in a biosatellite mockup where all flight factors, except for weightlessness, were simulated. It was found that exposure to weightlessness in the above intrauterine developmental period caused no serious changes in the behavioral reactions of rats during their postnatal development. The number of refusals and errors and the latency period were similar in the rats from the flight and control groups. Changes were seen only in fine behavioral regulation. The flown animals displayed a lower research activity in the open field, a longer time of search in the maze, a far longer time for grooming and a greater number of inadequate movements, and a stronger response to external inhibiting stimuli. These changes seem to be caused by a slight attenuation of the basic nervous processes (primarily, inhibitory) and a decrease of their balance and lability. These effects may be associated with an inhibitory influence of space flight factors on the maturation of cortical structures.

[Text] It is known that exposure of pregnant animals to various factors can impair development and functions of the brain in their offspring. Many works have been published on the prenatal effect of ionizing radiation [7, 10, 13], hypoxia [12], various chemicals [4, 6, 15, 21, 22] and protein deficiency in the diet [17-19, 25]. However, there was no information to date concerning the prenatal effect of weightlessness on higher nervous activity.

We studied here the prenatal effect of weightlessness on central nervous system function in rats flown in space.

Methods

The material for these studies was obtained from a combined experiment aboard Cosmos-1514 biosatellite, where it was first shown that a mammalian fetus can develop under spaceflight conditions. The experimental conditions and basic results were described previously [14]. Wistar rats (females) were flown in the biosatellite during the period of 13th to 18th days of the gestation period. After the flight, we kept five females until they gave birth, four of them delivered live offspring and one, stillborn. We used 16 animals from the offspring, 4 from each litter, in our present study.

To demonstrate the effects of weightlessness, we examined 19 control rats from 5 females kept in a mockup of a biosatellite on the ground during the same stage of pregnancy (13th-18th days) (synchronous control), where we simulated all flight factors with the exception of weightlessness. The second control group (vivarium control) consisted of 24 offspring of 5 females who spent the entire gestation period in the vivarium.

Behavioral reactions of these groups of animals were studied in the period of 30-90 days after birth in an "open field" and diversely designed mazes, using alimentary reinforcement.

Open field tests were performed at the age of 30, 51-53 and 88 days. We used a round open field (90 cm in diameter). We considered such parameters as horizontal and vertical motor activity, frequency of coming to the middle and relative distance of the path to the center of the field, standing on their legs, sniffing, grooming, amount of urine and feces.

The baby rats were tested in a Lechman maze from the 33d to 45th days, in a Dombrovskaya maze from the 58th to 72d days, and in a maze of an original design (on the order of a modification of the Kheb-Williams maze) from the 79th to 82d days.

The Lechman maze consists of a starting section, central field and three paths going away from the latter. The animals were given the task not to repeat the same path. Repeated travel in the paths was not reinforced and considered erroneous.

The Dombrovskaya maze has a start and finish compartments, six parallel paths, in each of which there are several locked doors and one open one. The animal had to find and learn the only path to the finish, where they were reinforced.

In the original maze there are numerous passages, dead ends, open gates, locked and unlocked doors. Here, the animal had to select the shortest of the many possible paths to the finish.

While working with the mazes, we recorded the number of times the animals refused to go through the maze, latency period and task performance time, number of mistakes or erroneous runs, inadequate (not aimed at performing the task) movements, standing up, frequency and duration of grooming.

Change in stereotype of the route and external inhibition were used as functional loads. The results were processed in accordance with Fisher's criterion, χ square and comparison of two series of regression [11].

Results and Discussion

In the open field test the flight group of rats showed some decline of all parameters studied (see Table). There was decrease in total and relative distance traveled in the central parts of the field, frequency of going to these regions, frequency of sniffing and standing up. The most significant deviations were referable to time spent in the center of the field and specific exploratory reactions--sniffing and standing up unsupported.

Exploratory activity of rats in open field at different stages of study

Parameter	Group of rats	Animal age, days			Reliability of differ.
		51	52	53	
Total length of path, arbitrary units [AU]	F	75,7	79,7	64,4	FV <0,01
	V	94,1	97,6	101,8	FS <0,01
	S	92,5	100,6	91,6	
Frequency of going to middle of field, AU	F	5,6	7,6	6,6	FV <0,001
	V	12,3	11,8	12,1	FS <0,001
	S	13,4	11,7	10,8	
Relative length of path in center of field, %	F	3,2	5,6	3,7	FV <0,001
	V	8,9	8,7	9,5	FS <0,001
	S	13,0	11,7	10.3	
Frequency of standing up leaning on wall	F	8,4	8,1	8,1	FV <0,01
	V	12,1	13,6	11,9	FS <0,001
	S	17,7	15,7	13,3	
Number of specific exploratory reactions	F	8,6	10,8	11,8	FV <0,01
	V	14,5	22,3	14,0	FS <0,001
	S	23,5	21,0	19,0	

Key: F, V, S) flight, vivarium and synchronous control groups of animals, respectively
FV) difference between parameters of F and V groups
FS) difference between parameters of F and S groups

The above changes were in the same direction at all tested times, but they were the most marked and reliably different from both controls in 51-53-day-old rats. In 30-day animals, not all of the parameters presented a reliable change, whereas in 88-day ones the deviations were no longer reliable. In flight group males there was significant increase in amount of excreta, as compared to control values, which was not observed in females (Figure 1).

The study of animal behavior in different mazes revealed that the basic characteristics were virtually the same in all groups: there was no difference in number of rats that coped with the task, number of refusals and errors, or in latency periods.

Changes were referable only to the finer aspects of control of behavior related primarily to the process of internal inhibition. They were the most noticeable during work in the Dombrovskaya maze.

In this group of rats, refusing to go through the Dombrovskaya maze was most often observed before the finish, when progressive alimentary excitation apparently elicited stress on the weakened inhibitory process and disruption

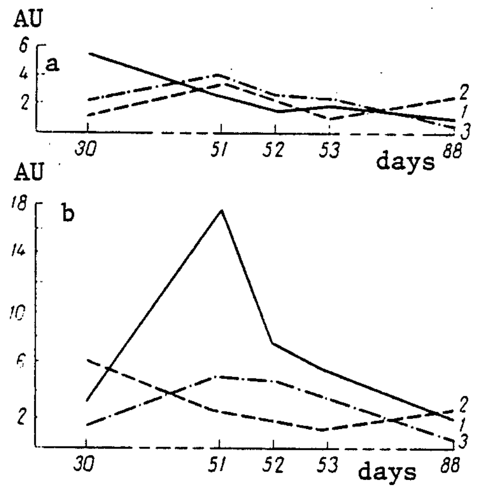

Figure 1.
Amount of excreta in females (a) and males (b) when exploring the open field; x-axis, animals' age (days); y-axis, amount of excrements (AU--arbitrary units). Here and in Figures 2 and 3:

1-3) animal groups: flight, synchronous and vivarium controls

of run stereotype. In the last paths of the maze, the flight group of animals refused to run in 50% of the cases, versus 18-20% in the control animals. There was very marked increase in grooming by these animals when working in the maze (number of grooming movements and grooming time), which was probably due to extensive irradiation of excitation in the presence of weakened internal inhibition (Figure 2). The experimental group of animals also had a large number of "inadequate" movements, i.e., unrelated to achieving their main goal (receiving additional food): standing up supported on the wall, shuttling through the paths without trying to open a door, bumping into the wall in the opposite direction from the finish point, going into dead ends and to the top of the maze, frequent lifting of the snout toward an open door, etc. The number of such movements did not diminish from experiment to experiment, as in the control groups, but held at the same level or even increased somewhat, which was apparently related to inertness of irradiated excitatory process.

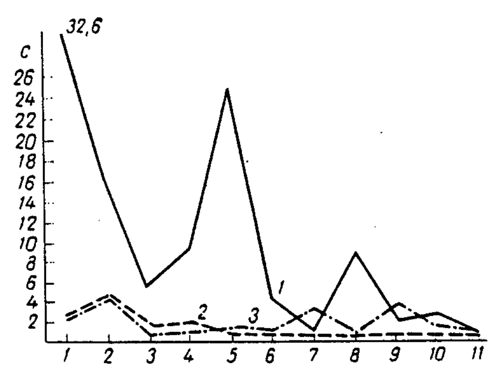

Figure 2.
Grooming time for different groups of animals in Dombrovskaya maze; x-axis, experiment number in maze; y-axis, grooming time during test (s) $P_{1-2}<0.01$, $P_{1-3}<0.01$

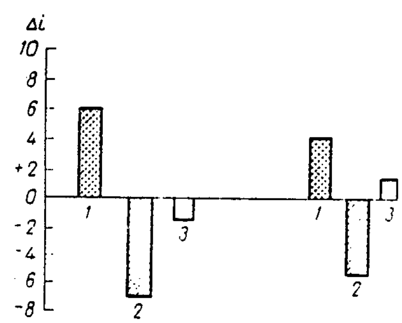

Figure 3.
Change (Δ_i) in number of inadequate movements (a) and mistakes (b) in Dombrovskaya maze after external inhibition; y-axis, increment in inadequate movements or errors after external inhibition as related to values before external inhibition. $P_{1-2}<0.01$, $P_{1-3}<0.001$

The flight group of animals spent more time ($P<0.01$) on performing tasks in all mazes (with about the same number of mistakes as in the control), and

the time diminished more slowly from experiment to experiment. There was also a slower decline in number of erroneous runs through the Lechman maze, as compared to the control groups.

The more marked reaction to an external inhibitory stimulus was also indicative of lesser lability of nervous processes in these animals. The number of errors, running time, number of inadequate movements and amount of grooming increased more than in control groups. The most appreciable differences were found as an aftereffect to external inhibition, i.e., performance of task after inhibition (Figure 3). Thus, while control animals usually presented a decrease in number of inadequate movements and errors (negative Δi) from run to run, this parameter rose in the experimental group (positive Δ_i).

It should be noted that males presented somewhat better characteristics than the females in the vivarium control group (for example, for all learning parameters in the Lechman maze, change in stereotype in the Dombrovskaya maze, etc.). However, in the flight and synchronous experiment groups, the males were often worse than the females, i.e., they demonstrated greater sensitivity to flight factors. Thus, the flight group males had longer latency periods and more erroneous runs in the Lechman maze, it was more difficult for them to readjust the movement stereotype in the Dombrovskaya maze, they presented considerably greater "emotionality" in the open field situation. The lower reactivity of females to various factors is biologically determined, and it is well-known in the literature [1, 8, 23, 24].

The results of our experiments indicate that changes due to prenatal exposure to spaceflight factors were not gross, and they did not elicit subsequent appreciable deviations in the animals' behavior. They were well-oriented in a new situation, assimilated the presented algorithms of behavior and used their experience in a different situation.

The nature of the observed changes is apparently attributable to some weakening of basic nervous processes (primarily inhibitory), decrease in their equilibrium and lability. Weakness of internal inhibitory processes was often associated with increased irradiation of the excitatory process.

The probability of such weakening of nervous processes is due to the fact that, in this experiment, exposure to spaceflight factors occurred at a time that is considered quite important in embryogenesis of the rat nervous system, according to data in the literature. It is characterized by formation of catecholaminergic neurons, synthesis of biogenic amines and DNA that are involved in functional maturation of the brain. At the same time, there is also the most intense division of neuroblasts and maturation of cellular elements in a number of cortical and stem structures [3, 5]. In addition, it is expressly in this period (17th day of embryogenesis) that rats have the first peak of cellular proliferation and establishment of basic structures of the hippocampus, which provides for the concentration of nervous processes and is particularly important to integrative brain function and regulation of behavior, as well as formation of orienting and exploratory reactions [2, 9].

All of the observed changes are nonspecific, and we know about them from the literature, in relation to the effects of the most varied factors: radiation,

hypoxia, pharmacological agents. There were also several functional and, sometimes, histomorphological changes in brain structures of the offspring: poorer learning ability and slower reflex responses, difficulty in development of differentiation, increased number of intercue responses, increased emotionality in the open field, decrease in weight of the brain, number of nerve cells, dendrites and terminal branches of brain stem reticular cells [6, 10, 12, 15-22].

Examination of animals in the synchronous control group revealed that, in this experiment too, the dynamic factors (with the exception of weightlessness) associated with flight were not indifferent to formation of behavioral reactions in the offspring. The nature of the overall effect with addition of weightlessness was apparently determined by the patterns of the combined effect of a number of factors.

The minor deviations demonstrated in the flight group of animals with regard to fine regulation of behavior can be evaluated as the result of weaker inhibitory effect of the cortex on subcortical elements, which is apparently attributable to some retarding influence on maturation of functional cortical structures by the prenatal exposure to flight factors. The noted changes are insignificant under ordinary conditions, but they could be the potential cause of narrower range of efficiency of the central nervous system and could lower the body's adaptation to exogenous conditions, which must be taken into consideration in particular in case of difficult situations and limited time.

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UDC: 612.75:612.647].014.477-064

EFFECT OF WEIGHTLESSNESS ON RAT FETUS SKELETAL DEVELOPMENT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 6 Feb 85) pp 60-63

[Article by L. A. Denisova]

[English abstract from source] The size of the ossified areas of skeletal bones of fetuses of white rats flown onboard Cosmos-1514 during their pregnancy days 13 to 18 was compared to that of synchronous and vivarium controls. The effect of zero-g on the pregnant animals in the course of an active formation of fetal bones involved a distinct (13-17%) arrest of the development of nearly every area of the fetal skeleton. The signs of the arrest development were more manifest in less mature skeletal structures. Since the Ca^2 content was identical in the flight and control rats, it can be concluded that the inhibited ossification of the flight fetuses was produced by the impairment of mechanisms controlling Ca^{2+} incorporation into the growing skeleton. The ossified areas in the skeleton of the flight newborns were significantly larger than those of the synchronous and vivarium controls. This means that during the readaptation period (pregnancy days 18 to 23) the inhibited ossification of the fetal skeleton was completely compensated and that the flight newborns (i.e. the rats whose prenatal development occurred in part in zero-g) were ahead of the controls with respect to the ossification rate.

[Text] A study was made of the effect of weightlessness on ossification processes in the developing rat fetus during active growth, development and differentiation of the skeleton, when there is a high level of assimilation of Ca^{2+} by new bone.

Methods

These studies were conducted on fetuses and neonate rats born to 4-month animals (Wistar population) from the Stolbovaya Nursery. The data were obtained in a combined experiment aboard Cosmos-1514 biosatellite. Experimental conditions and principal results were reported previously [1].

The animals in the 1st (flight) group were flown aboard the biosatellite from the 13th to 18th days of the gestation period. The 2d group (synchronous control)

was submitted to all spaceflight factors (temperature and gas conditions, factors related to launch and landing of the biosatellite) with the exception of weightlessness in a ground-based model experiment. The 3d group of animals (vivarium control) were kept in ordinary cages under vivarium conditions. All three groups of animals were given feed in paste form and water ad lib. Some animals from each group were dissected on the 18th day of the gestation period, taking 3-4 fetuses from each to examine the skeletal bones. Part of the animals were kept until natural delivery of offspring, which usually occurred on the 23d day of pregnancy. For examination of the skeleton, we used neonates 2-3 h after birth. We took 1-3 neonates from each mother. In all, we examined 20 fetuses and 14 neonates from 9 females of the 1st grup, 20 fetuses and 10 neonates from 9 females in the 2d group, 20 fetuses and 20 neonates from 14 females in the 3d group.

Fetuses and neonates were fixed in 96° ethanol, after which soft tissues were cleared by the Dawson method [2], using an alkaline solution, and bone stained with alizarin red. The areas of ossification in primordia of the mandible, bones of the shoulder and pelvic girdles were measured in the direction of maximum longitudinal size using the ocular micrometer of an MBS-9 magnifier. In addition, we measured the length of the tail, cartilaginous primordium of the shoulder in 18-day fetuses, as well as in the shoulder and thigh of neonates. The results were submitted to statistical processing using Student's t criterion.

Results and Discussion

Normally, ossification centers are demonstrable on the 18th day of prenatal development of rat fetuses in the clavicle, scapula, humerus, ulna and radius, in the pelvic girdle--femur, tibia, fibula and ischial bone. The primordia of other bones of the extremities are represented by cartilage. At this stage of development, ossification of vertebrae extends only to the lumbar region. The mandible is the largest bone at this stage. Some ossification sites appear in the connective tissue primordia of frontal and temporal bones.

A comparison of the length of ossification areas in the skeleton of 18-day fetuses referable to the flight and both control groups established that exposure of pregnant animals to weightlessness in the period of active formation of bone tissue in fetuses was associated with distinct retardation of ossification in virtually all parts of the skeleton (Table 1). Less mature skeletal structures were found to be more sensitive. Retarded ossification was more marked in primordia of the pelvic girdle bones we measured than in the shoulder girdle, the latter being virtually 1 day ahead in development, as compared to the hind extremity. While, the area of ossification in the anterior limb was 13% shorter in flight group fetuses than in the synchronous control, the retardation constituted 20% for the posterior limb fetal bones, as compared to the control ($P<0.05$).

Exposure to weightlessness also affected development of cartilage: the delay in longitudinal development of cartilaginous primordium of the humerus constituted 5% in the 1st group, as compared to the 2d ($P<0.05$). The tail of experimental fetuses was also shorter by a mean of 5%. While the fetuses in both

control groups each had 3 ossification centers in the lumber spine region, those in the 1st group had only a mean of 2 ossification centers in lumbar vertebrae (P<0.05).

Table 1. Length of regions of ossification in primordia of bones in 18-day fetuses from rats submitted to spaceflight factors from the 13th to 18th day of gestation period (mm)

Bone	Group		
	1	2	3
Clavicle	1,42±0,03*	1,59±0,02°	1,45±0,03
Scapula	0,69±0,02*°	0,78±0,02	0,79±0,03
Humerus	0,82±0,03	0,89±0,03	0,89±0,03
Ulna	0,66±0,03*°	0,81±0,02	0,77±0,03
Radius	0,57±0,03*	0,67±0,02	0,63±0,04
Femur	0,34±0,02*°	0,44±0,02	0,43±0,02
Tibia	0,36±0,03	0,43±0,03	0,46±0,05
Fibula	0,29±0,02*°	0,37±0,02	0,39±0,04
Ischium	0,55±0,01*°	0,66±0,02	0,66±0,04
Mandible	3,70±0,11	3,85±0,08	3,73±0,08

Note: We examined 20 fetuses in each group. Here and in Table 2:
*) reliable (P<0.05) difference from parameters of 2d group
°) " " " " " " 3d group

There was virtually no difference in any parameter between the skeleton of fetuses in the 2d and 3d groups. Consequently, the factors related to launching and landing the biosatellite, as well as gas and temperature environment, affected [sic] the rate of development and mineralization of the fetal skeleton. Thus, the changes demonstrated in the skeleton of 1st group fetuses can be attributed to weightlessness.

The neonate skeleton was examined 5 days after the mothers returned to earth. In this period, development of fetal bone took place in the presence of changes in their mothers, which developed during readaptation to earth's gravity. On the 23d day of normal fetal development, which is when it is delivered in rats, there are ossification centers in primordia of virtually all skeletal bones, with the exception of the last caudal vertebrae and distal phalanx of the anterior and posterior extremities. Analysis of the findings revealed that the areas of ossification are reliably larger in the neonate skeleton in the 1st group than in the 2d and 3d groups (Table 2). This difference is more marked for primordia of the pelvic girdle bones, constituting 17% in newborn rats of the 1st group, as compared to the 2d group, whereas the analogous difference constituted a mean of 11% in the shoulder girdle bones. In the period of maternal readjustment to earth's gravity there was also stimulation of development of skeletal cartilage: in the 1st group of neonates, the length of the cartilaginous primordium of the humerus was 7.33±0.11 mm, versus 6.84±0.15 in the 2d group (P<0.02), that of the femur was 6.75±0.13 and 6.24±0.11 mm, respectively (P<0.01). The 1st group presented a longer jaw and tail than the 2d and 3d groups. Appearance of new ossification centers in cartilaginous primordia of the caudal spine occurred earlier in the 1st group of neonates

than in the 2d and 3d group offspring. Thus, while an average of 4 ossification centers were noted in the caudal vertebrae of neonates in the 2d group, there were a mean of 7 ossification centers in neonates of the 2d group ($P<0.05$). Consequently, not only was there compensation of ossification processes in the fetal skeleton, but stimulation of these processes in the period of re-adaptation of pregnant animals, and this occurred to such an extent that there was an increase in rates of fetal skeleton development in the 2d and 3d groups.

Table 2. Length of ossification areas in skeletal bones of neonates exposed to spaceflight factors from the 13th to 18th days of prenatal development (mm)

Bone	Group		
	1	2	3
Clavicle	4,51±0,05*	4,06±0,09	4,23±0,06
Scapula	4,34±0,08*	3,86±0,09	4,08±0,06
Humerus	4,55±0,06*	4,14±0,09	4,34±0,07
Ulna	5,14±0,07*	4,66±0,12	4,69±0,07
Radius	3,89±0,05*	3,44±0,07	3,63±0,04
Femur	3,73±0,04*	3,33±0,10	3,45±0,08
Tibia	4,62±0,11*	4,05±0,11	4,13±0,08
Fibula	4,25±0,09*	3,76±0,10	3,82±0,06
Ischium	2,18±0,09*	1,75±0,06	1,76±0,04
Pubic	1,81±0,06*	1,44±0,06	1,57±0,04
Ilium	3,00±0,07*	2,66±0,07	2,80±0,05
Mandible	10,57±0,21*	9,89±0,06	9,79±0,14

Note: We examined 14 neonates from the 1st group, 10 from the 2d and 20 from the 3d group.

With reference to the mechanisms of the described phenomena, it must be assumed that most of them are attributable to changes that occurred in the mothers. K. E. Tsiolkovskiy had already demonstrated by calculations that, thanks to the amniotic fluid surrounding the fetus, it is much less susceptible to the effect of altered gravity than its mother. Changes in fluid-electrolyte homeostasis in the mother, her development of a stress reaction during adaptation to flight conditions and efflux of blood from vessels of abdominal organs may also be important to development of the fetal skeleton in weightlessness.

Examination of fluid-electrolyte composition of maternal organs and fetal tissues performed in the same experiment revealed rather marked changes in calcium metabolism in the rats exposed to weightlessness in gestation period. Interestingly, considerable loss of Ca^{2+} was demonstrated in renal and hepatic tissues, wherease bone Ca^{2+} content was unchanged. Fetuses that developed in weightlessness presented a lower weight and higher fluid content than fetuses in the 2d and 3d groups. However, when scaled to the unit of wet and dry tissue, as well as fetus as a whole, Ca^{2+} content was the same in the experimental and control groups. Thus, the delayed ossification in the 1st group of fetuses was not attributable to Ca^{2+} deficiency in fetal tissues, but most probable to impairment of mechanisms that control the process of incorporation of Ca^{2+} in the developing skeleton. The fact that, along with retarded development of bone primordia, there was also

delayed development of cartilage primordia warrants the assumption that the retarded skeletal development could be largely due to defects in organic component of bone.

An interesting and unexpected finding was the faster skeletal development in the 1st group of fetuses at the end of the prenatal period, during their mothers' readaptation to earth's gravity. Unfortunately, Ca^{2+} content was not measured at this time either in the fetus or its bones. It can be assumed that, in this case, as in the prior orbital experiments on animals, there was a positive Ca^{2+} balance in the maternal body, including fetal tissues, in the recovery period. With normalization at this time of mechanisms that control incorporation of calcium in developing bone, the more intense deposition of this ion in bone could be the cause of acceleration of mineralization processes in the skeleton of the 1st group of fetuses.

The pregnant animals were exposed to a change in gravity twice in the course of the experiment: the first time, experiencing a weight reduction with change from earth's conditions to weightlessness and the second time, weight gain with change from weightlessness to earth's gravity. In each case, the direction of changes noted in the fetal skeleton coincided with the direction of changes observed in the skeleton of adult animals exposed for a longer time to weightlessness during flights in biosatellites and to chronic use of accelerations in centrifuge experiments. However, the effects were more acute and manifested at an earlier time in the skeleton of a developing fetus.

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UDC: 612.766.2-08:612.433.65.014.2

FUNCTIONAL STATE OF SOMATOTROPIC CELLS OF ADENOHYPOPHYSIS IN HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 29 Jan 85) pp 63-67

[Article by Ye. I. Alekseyev]

[English abstract from source] Morphological and cytokaryometric examinations of the somatotropic cell population of the rat pituitary anterior lobe were performed on hypokinetic days 30, 90 and 165, and 60 days after 165-day hypokinesia (readaptation period). During prolonged hypokinesia the major changes occurred in the cytoplasm of somatotropic cells and were accompanied by an inhibition of the growth hormone synthesis. A higher activity of somatotropic cells during readaptation suggested that diminished motor activity may be responsible for a lower hormone production in the pituitary. The experimental findings and published data allow the conclusion that the inhibition of animal growth which takes place during hypokinesia is closely associated with an inhibited somatotropic function.

[Text] It is known that hypokinesia leads to a complicated set of pathological disorders in man and animals [6]. Thus, rats showed significant morphological and functional changes in different systems of tissues and organs, as well as drastic retardation of development [3-5, 9-11]. It is assumed that depression of metabolic and growth processes under hypokinetic conditions is related, to some extent, to impairment of somatotropic function of the pituitary gland [3, 4, 6]. This is confirmed in part by clinical observations of decrease in growth hormone content in blood of individuals who spent a long time in bed [14, 21]. However, the assumption is still debatable in view of the absence of factual material concerning the nature of morphological manifestations of reactions of adenohypophysial somatotropic cells in response to long-term restriction of animals' motor activity.

We submit here the results of a morphological and cytokaryometric study of the somatotropic population of cells in the anterior lobe of the rat pituitary during long-term hypokinesia and in the recovery period.

Methods

These studies were performed on white male Wistar rats with a base weight of about 300 g (age 2.5 months). Hypokinesia was produced by means of box-cages

that restricted animal mobility considerably. Control groups of rats were kept under the usual vivarium conditions and received the same feed as experimental animals. The rats were sacrificed using ether on the 30th, 90th and 165th days of hypokinesia, as well as 2 months after it (recovery group). We examined the pituitary from 6 rats in each experimental and control groups. The material was fixed in Bouin's fluid, imbedded in paraffin, and we then prepared horizontal serial sections. For demonstration of somatotropic cells, pituitary preparations were stained with paraldehyde fuchsin and Helmy's mixture [2]. The functional state of somatotrophs was evaluated according to the aggregate of information obtained concerning the dimensions of cells and nuclei, quantitative relations between the nucleus and cytoplasm, amount of oxyphilic (hormonal) substance in cytoplasm according to its optical density when stained with orange G [7, 16-18]. Cytokaryometry of ST [somatotropic] cells was performed using an RA-6 drafting machine at 3000× linear magnification. We drew in 100 nuclei and 50 outline projections of stomatotrophs situated along capillaries in pituitary sections from each animal. The conventional morphometric methods were used [12] to measure diameters of nuclei and cells, calculate their volume and submit digital data to statistical processing.

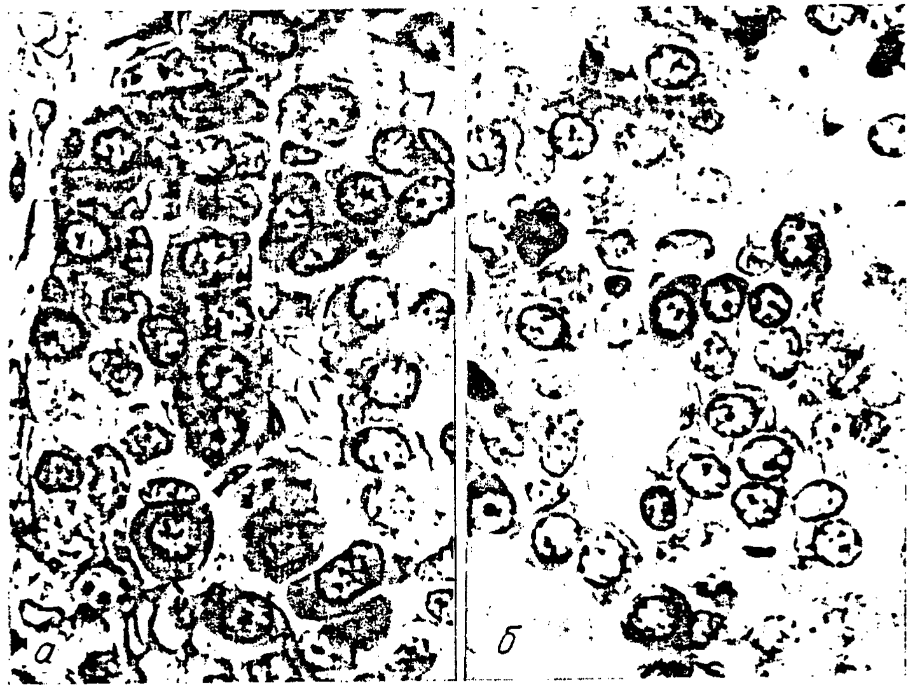
Results and Discussion

As their age progressed from 2.5 to 10 months (the period corresponding to total duration of experiments), vivarium control rats showed virtually no change in either the size of ST cells proper or in their nuclei. In this respect, morphometry of somatotrophs in control groups of rats, which differed markedly in age, was particularly demonstrative. Thus, in 3.5-month animals (control for group submitted to 30-day hypokinesia), the volumes of the cells in question and their nuclei constituted 438.0±9.0 and 146.0±3.9 μm^3, respectively, and when they reached the age of 10 months (control for recovery period group) the figures were 412.1±10.2 and 135.0±3.0 μm^3. The absence of reliably significant age-related changes in the tested parameters of rats in the vivarium control group enabled us to combine the mean parameters of volume of somatotrophs and nuclei (see Table).

Results of cytokaryometry of rat adenohypophyseal somatotrophs

Rat group	Volume, μm^3					Nucleus/cytoplasm ratio (n:c)
	cells (M±m)	P	nuclei (M±m)	P	cytoplasm (M)	
Vivarium control	417,5±8,5		138,0±3,9		279,5	1:2,0
Submitted to hypokinesia for:						
30 d	389,6±10,0	<0,1	136,0±2,4	<0,7	253,6	1:1,9
90 d	289,6±13,5	<0,001	140,8±3,1	<0,5	148,4	1:1,0
165 d	466,0±11,3	<0,01	132,6±6,0	<0,5	333,4	1:2,5
Recovery group	482,8±9,0	<0,001	158,9±1,3	<0,01	323,9	1:2,0

Note: The values for P are given in relation to parameters of vivarium control.



Anterior lobe of rat pituitary; lens 40×, eyepiece 8×; paraldehyde fuchsin and Helmy mixture staining

a) control--somatotropic cells have wide bands of cytoplasm, which presents a uniformly oxyphil (hormonal) substance
b) experiment--90 days of hypokinesia; prevalence of small somatotrophs with barely discernible dust-like accumulations of oxiphil substance in cytoplasm

On the 30th day of hypokinesia we observed distinct attenuation of oxyphilia of most ST cells, particularly those situated along capillaries. They presented lower optical density of cytoplasm due to friability and decrease in its oxyphilic substance content. In spite of the same dimensions of cells and nuclei (see Table), the somatotrophs of experimental animals could be readily distinguished from those of vivarium control rats.

Upon completion of the 90-day experiment, the rat adenohypophysis revealed extremely low oxyphilia of ST cells. In most somatotrophs situated either along the course of the dilated capillaries or in the intervascular glandular compartments, the cytoplasm virtually failed to take up orange G and appeared optically transparent ("empty") or contained dust-like accumulations of oxyphilic substance that could be barely discerned upon immersion inspection. At the same time, there was significant decrease (to 50% on the average) in volume of cytoplasm, whereas cell nuclei were similar to the control in size (see Table and Figure). Such marked reduction in dimensions of somatotrophs and depletion of their cytoplasm made it very difficult to identify them, which could have led to an erroneous conclusion as to the true number of ST cells. Apparently, this is what happened in the study of Ye. P. Tsvetov et al. [13].

On the 165th day of hypokinesia, oxyphilia of most somatotropic cells remained appreciably lower than in the vivarium control. However, along the capillaries there appeared some rather large cells with high oxiphil substance content. On the average, the volume of cytoplasm of all variants of ST cells encountered near the walls of blood vessels increased by about 20%. Nevertheless, the increase in somatotroph volume was not associated with any change in size of their nuclei (see Table).

It should be noted that the decrease in ST oxyphilia was associated in these animals with impairment of quantitative relations between the nucleus and cytoplasm, particularly with increase in duration of the experiment. Thus, while there was merely a tendency toward elevation of nucleus-cytoplasm ratio on the 30th day of hypokinesia, by the 90th day it rose drastically and by the 165th day, on the contrary, it dropped. The decrease or increase in size of somatotrophs occurred as a result of the corresponding change in volume of cytoplasm, whereas the nuclei retained a constant volume at the level inherent in control animals (see Table).

Two months after termination of 165-day hypokinesia, oxyphilia of the somatotropic cell population was entirely restored to the level observed in intact animals. Normalization of oxyphilic substance content in the cytoplasm of somatotrophs was associated with distinct increase in volume of the cells and their nuclei (see Table). We were impressed by the presence of a large number of ST cells along the course of numerous blood capillaries, with signs of marked degranulation of cytoplasm in the region of its contact with the vascular wall. The similar increase in volume of nuclei and cytoplasm of somatotropic cells did not lead to change in the quantitative relationship between them (see Table).

Thus, the main morphological parameters reflecting the functional state of ST cells remained stable in vivarium control rats at all tested times (from the age of 3.5 to 10 months). As we know, this is the period when there is appreciable slowing of gain in weight of body and viscera of rats [8].

The significant inhibition and, according to some parameters, virtually complete arrest of growth (of skeletal muscles and heart) in these experimental conditions [3, 4] served as the main reason for investigating somatotropic cells of the anterior lobe of the rat pituitary gland. The results of the study revealed that the volume of ST nuclei persisted on the same level in the course of long-term (165-day) hypokinesia and was the same as in control animals. The main changes in ST cells were demonstrable in their cytoplasm. Diminished oxyphilia was the most typical change at all stages of hypokinesia. It reached a maximum on the 90th day of the experiment, when the size of somatotrophs decreased to almost one-half, while the cytoplasm virtually failed to take up a stain (orange G). The degree of oxyphilia of ST cell cytoplasm is one of the morphological indicators of growth hormone content. This was confirmed in studies in which a comparative evaluation was made of intensity of somatotroph oxyphilia (with use of orange G stain) and their hormone content using immunocytochemical and electron microscope methods [16-18]. According to the foregoing, it may be assumed that, in the course of long-term hypokinesia, there was inhibition of somatotropic hormone synthesis and, accordingly, a decrease in its level in the adenohypophysis. According to the results of biochemical studies, long-term bedrest leads to a substantial and persistent decrease in human blood growth hormone content [14, 21]. In spite of the presence of substantial

differences between human and animal models of hypokinesia, the feature in common is limited motor activity. It can be concluded from this that it is expressly restriction of motor activity that may be the basis for the decrease in somatotropic hormone content of the pituitary (in animals) and blood (in man). This was also confirmed by the significant increase in functional activity of ST cells when the rats resumed their usual motor activity.

In the recovery period (even after 2 months), the rat adenohypophysis showed substantial enlargement of somatotrophs and their nuclei, while the observed recovery of oxyphilia to its normal level concurrently with degranulation of cytoplasm in the region of its contact with capillary walls were indicative of intensification of synthesis and release of the hormone into blood. There was also considerable weight gain, in particular, by the skeletal muscles of the animals [3]. Activation of somatotropic function of the rat hypophysis after hypokinesia is also consistent with data concerning increased secretion of growth hormone in the case of high physical loads [1, 15, 19, 20].

On the basis of the obtained data, it can be concluded that depression of functional activity of the somatotropic population of cells in the anterior lobe of the pituitary gland is one of the mechanisms of slowing animal growth and impairment of tissue metabolism during long-term hypokinesia.

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UDC: 629.78:616.74-008.922.1-008.61-092.9-07

NOREPINEPHRINE USED TO CONTROL ENERGY OF HEAT PRODUCTION AND UTILIZATION OF ATP IN SINGLE MUSCULAR CONTRACTION UNDER NORMAL AND HYPEROXIC CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 10 Sep 85) pp 67-72

[Article by L. D. Pchelenko]

[English abstract from source] The effect of noradrenalin (NA, 0.008 μg/ml) on the rate of heat release (V) during a single isometric contraction of an isolated diaphragm was investigated in rats kept in air and 99% oxygen for 3 hours. The effect was measured by the electrothermometric method in the presence and in the absence of ATP (0.01 mg/ml) in the incubation solution. Hyperoxia doubled V of muscle contraction. The calorigenic effect of NA was not detected in the norm and was very distinct during hyperoxia so that $V_{NA} = 0.14 \times V_{init} + 10.88$. ATP increased V both in the normal and hyperoxic state. However, the increase of the initial V level was 5.3-fold in the hyperoxic state and 1.5-fold in the norm. It is concluded that hyperoxia disturbs energy metabolism of muscle contraction through NA-dependent acceleration of ATP-lytic processes and increase in energy expenditures of heat formation in the course of muscle contraction.

[Text] Energetics of the muscular system under the extreme conditions of spaceflights merit the closest attention, since they ultimately determine work capacity and physical endurance. There is information to the effect that energy metabolism is impaired in muscles of animals flown in space [2]. It is important to determine whether the energy cost of a single muscular contraction changes during adaptation to space factors and the extent of such change. Energy utilization by muscles functioning under extreme conditions may serve as one of the limiting criteria with respect to permissible duration of stays in space.

The outlay of endogenous energy by a muscle during contraction is estimated in accordance with the first law of thermodynamics, according to amount of heat released. Unfortunately, due to methodological difficulties, the vast majority of heat measurements, starting with the classical work of A. W. Hill [9], were made on isolated muscles of cold-blooded animals. However, there is only sparse information of muscle energetics for warm-blooded animals and was obtained in most cases at temperatures of 20-24°C, i.e., under conditions that do not correspond to in vivo temperature conditions. With a modification of the method in

[9] for studies of contractions of the isolated rat diaphragm at 37°C, it was found that the energetics of this respiratory muscle are extremely sensitive, even to single exposure to hyperoxia [5]. Since the question of effects of high concentrations of oxygen is of interest to space biology and medicine, subsequent investigations dealt with determination of the mechanisms of hyperoxic enhancement of contractile heat production. This calorigenic effect of hyperoxia warrants the belief that factors with a powerful metabolic influence on energetics of muscle cells are involved in its origin, in particular, catecholamines, since the influence of blood flow and the central nervous system is ruled out under conditions of in vitro incubation. Activation of the sympathoadrenal system under the influence of high concentrations of oxygen has been proven by several authors [4, 6]. At the present time, it is believed that the calorigenic effect of catecholamines on energy metabolism of muscle cells is implemented through β-adrenergic activation of the adenylate cyclase mechanism--cAMP, which mobilizes increased amounts of hexosophosphates and, thus, stimulates substrate thermogenesis [3]. In this article, we analyzed the rates of heat release with a single contraction of the isolated rat diaphragm in three successive modes of incubation of muscle preparations, saline → norepinephrine (NE) → ATP, in order to investigate expenditure of energy in the muscle of animals submitted to brief hyperoxia.

Methods

Experiments were conducted on white mongrel rats of both sexes weighing about 200-250 g. The 1st group of animals consisted of 9 control rats kept in the vivarium and the 2d, of 11 rats submitted once for 3 h to 99% oxygen under isobaric conditions.

The animals were sacrificed by the method of rausch anesthesia, after which the diaphragm was carefully excised on a costal ring. The right half of the diaphragm was secured by means of needles along the periphery on a special thermopile, and the ribs were removed. In this form, the preparation was placed in a heat-controlled chamber at 37°C and incubated in the original saline (aerated Krebs-Henseleit solution). After temperature stabilization was obtained in the chamber, the muscle was stimulated with single pulses (20 V, 16 ms) every 5 min. Temperature measurements were taken at the time of the isolated isometric contractions of the diaphragm by means of a thermometric system, the sensitivity of which constituted $1 \cdot 10^{-5}$ °C/mm. Concurrently, we recorded isometric tension with a strain gage. We analyzed the ascending front of thermograms, from the build-up rate of which we determined the rate of heat release in the 1st second after stimulation, which was referred to as V (in millicalories/g muscle weight/s). In addition, we calculated the index of energy cost of each gram of isometric tension (F) that is developed by the muscle and designated as V/F (mcal/s/g muscle tissue/g isometric tension of muscle).

The protocol of the experiment consisted of the following. After 30-min incubation of the muscle in Krebs-Henseleit solution, we took the 1st series of temperature readings, in which the sought rate of heat release during contraction was referred to as V_1. We then added NE to the incubation solution so that its end concentration would be 0.008 μg/mℓ. The muscle was immersed in this solution for 10 min, then the temperature readings were repeated. The sought rate of heat release was referred to as V_2. Finally, six preparations

of muscles from each animal group were tested a third time, for which purpose we added ATP (0.01 mg/mℓ) to the incubation solution containing NE. The muscle was immersed in this solution for 5 min, after which the temperature was again measured, and the recorded rate of heat release was designated as V_3. We made 3-4 thermograms in each incubation mode, the total being 9-11 thermograms for the entire experiment.

Additional experiments on 10 experimental and 10 control rats were conducted to measure diaphragm creatinine content by the standard clinical method and for histochemical analysis of the adrenal medulla [10].

Results and Dicussion

Analysis of thermograms of single isometric contractions of the rat diaphragm referable to the control and experimental groups revealed drastic differences in rate of heat release both in the baseline state and after use of pharmacological agents on muscle preparations. Table 1 lists the results of temperature readings for single isometric contractions of the isolated diaphragm of control animals. As can be seen in this table, normally (in baseline state), prior to use of pharmacological agent, the muscle preparations from control animals release heat at a mean rate of about 3.52±0.60 mcal/s/g per contraction. The subsequent 10-min soaking of these muscles in solution containing NE led to some increase in heat release rate V_2 and isometric tension F_2 (by 34 and 14%, respectively); however, these changes were unreliable. Addition of ATP to the incubation solution elicited consistent though slight increase in heat release rate V_3. A marked positive correlation was demonstrated between V_2 and V_3, expressed by an equation of linear regression: $V_3 = 1.07 \cdot V_2 + 0.70$ ($r = 0.96$, $P<0.01$). Analysis of the index of energy cost of muscular contraction (V/F) for preparations from the control group of rats revealed that, in the baseline state, for each gram of developed isometric tension, with contraction the muscle releases 0.29±0.06 mcal/s/g, and this figure is insignificantly higher with use of NE and ATP. In other words, the normal thermodynamic response of muscle preparations during contraction in the presence of excessive NE and ATP is reserved in level and conservative in content, which may be indicative of reliable cellular control of utilization of energy resources in the intact muscle cell. The findings were quite different for muscle preparations from rats submitted once to 3-h hyperoxygenation (Table 2). The differences, in comparison to muscles of control animals, consisted of the following. In the first place, baseline rate of heat release V_1' increased by a mean of 2.2 times in the experimental group of muscles and constituted about 7.81±0.98 mcal/s/g. Energy cost of each gram of tension developed with contraction also was 2 times greater and constituted a mean of 0.48±0.05 mcal/s/g ($P<0.05$). In the second place, high sensitivity to NE and ATP was demonstrated in muscle preparations from hyperoxic rats. This was manifested by appearance of a marked positive correlation between heat release rates before (V_1') and after (V_2') NE, and it was described as $V_2' = 0.14 \cdot V_1' + 10.88$ ($r = 0.96$, $P<0.001$). Under the effect of NE, the muscles of experimental group animals also showed increase in isometric tension, but the energy cost of contractions under the effect of NE increased by 33%, as compared to the control. Subsequent addition of ATP led to increase in energy cost of muscular contractions by another 57%, and heat release rate V_3' constituted 18.76±2.80 mcal/s/g ($P<0.05$). Figure 1 illustrates the vectors of mean rates of heat release during contraction for all three

incubation conditions for preparations from animals in the control and experimental groups. Figure 2 illustrates mean values for index of energy cost/g isometric muscle tension (percentage of control) for all three modes of incubation of preparations under normal and hyperoxic conditions. As can be seen from these figures, the increase in rate of heat production in a single muscle contraction in the diaphragm of rats submitted to 3-h hyperoxygenation once, and further increase of this parameter under the effect of NE and ATP are associated with concurrent increase in energy cost of the muscle contraction proper. Analysis of creatinine content in muscles of animals in the experimental and control groups revealed that, as a result of 3-h use of oxygen, creatinine concentration increased by a mean of 69% ($P<0.05$), which is indicative of more intensive dissociation of creatine phosphate in muscles of experimental group rats and is consistent with the results of temperature measurements, which indicated that there was more intense expenditure of energy for muscular work in the case of hyperoxygenation. Histochemical analysis of the adrenal medulla revealed that the experimental group of animals was characterized by noradrenacytes with 36% smaller than normal diameter of nuclei, which is indicative of activation of the medulla and intensification of NE secretion under the influence of hyperoxygenation, and apparently reflects the nonspecific stress of effect of brief exposure to oxygen.

Table 1. Heat release rate (V, mcal/g/s), mechanical tension (F, in g) and index of energy cost/g tension in single isometric contraction of isolated rat diaphragm (V/F) before and after using NE (0.008 μg/mℓ) and ATP (0.01 mg/mℓ) under normal conditions

Exper.	Baseline			NE			ATP		
No	V_1	F_1	V_1/F_1	V_2	F_2	V_2/F_2	V_3	F_3	V_3/F_3
1	5,44±0,24	18,0±1,1	0,30	5,35±0,17	20,0±1,5	0,27			
2	2,30±0,41	18,0±0	0,13	6,53±0,23	40,1±4,2	0,16			
3	2,78±0,16	17,3±0,6	0,16	7,34±0,60	25,1±2,6	0,29			
4	6,82±0,32	10,3±0,2	0,68	8,51±0,41	10,0±0,9	0,85	9,47±0,72	15,1±0,4	0,63
5	2,38±0,06	30,0±0,7	0,08	1,85±0,03	10,0±1,2	0,18	2,07±0,45	10,0±0	0,21
6	4,64±0,15	10,0±0	0,46	4,03±0,18	20,1±0,7	0,20	6,29±0,31	20,0±0	0,31
7	2,51±0,08	18,4±0,3	0,14	4,00±0,30	12,0±0,3	0,33	4,78±0,18	15,5±0,4	0,32
8	1,18±0,03	4,0±0,2	0,29	2,35±0,21	7,2±0,2	0,34	2,69±0,01	10,0±0	0,27
9	3,59±0,07	10,2±0,5	0,36	2,64±0,42	10,3±0,7	0,26	3,97±0,6	15,0±0	0,26
$M\pm m$	3,52±0,60	15,0±2,5	0,29±0,06	4,73±0,78	17,1±3,5	0,32±0,07	4,88±1,10	14,2±1,5	0,33±0,06

On the whole, this study demonstrated the relative stability and moderation of energy expenditure in muscles under normal conditions, the thermodynamic independence of energetics of these muscles from excessive NE and consistent, though insignificant, increase in rate of heat production during contraction under the influence of excessive ATP. Unlike this, rat muscles kept for 3 h in an atmosphere of 99% oxygen showed a two-fold higher base level of energy expenditures, as compared to the control, during muscle contraction and high sensitivity to excessive NE and ATP, according to parameter of heat release rate. The obtained data confirm the hypothesis [8] to the effect that impairment of energy metabolism of the cell is the main factor in oxygen-related pathology.

Table 2. Heat release rate (V', mcal/g/s), mechanical tension (F', g) and index of energy cost/g tension (V'/F') in single isometric contraction of isolated rat diaphragm before and after use of NE (0.008 μg/mℓ) and ATP (0.01 mg/mℓ) following 3-h hyperoxia

Exper. No	Baseline			NE			ATP		
	V_1'	F_1'	V_1'/F_1'	V_2'	F_2'	V_2'/F_2'	V_3'	F_3'	V_3'/F_3'
1	3,78±0,22	7,0±0	0,54	8,36±0,32	7,1±0,3	1,19			
2	5,11±0,18	10,2±0,4	0,51	9,57±0,42	20,3±0,2	0,48			
3	10,30±0,61	30,0±0	0,34	10,36±0,27	26,1±0,6	0,40			
4	5,43±0,30	20,4±0,3	0,27	5,13±0,41	20,3±0,7	0,26			
5	10,69±0,38	20,0±0,5	0,53	9,71±0,92	20,6±0,4	0,48			
6	3,25±0,17	20,3±0,5	0,16	13,03±0,04	30,0±0	0,43	19,27±0,63	35,4±0,7	0,55
7	11,07±0,72	20,4±0,6	0,55	11,80±0,21	20,3±0,1	0,59	20,76±0,40	25,6±0,5	0,83
8	9,47±0,51	15,5±0,4	0,63	9,76±0,74	15,3±0,8	0,65	10,16±0,76	16,2±0,6	0,63
9	11,11±0,53	22,2±0,7	0,50	13,68±0,18	25,0±0	0,55	23,26±1,04	30,4±1,3	0,77
10	10,72±0,28	15,4±0,7	0,71	18,48±0,42	20,5±0,4	0,92	27,78±0,82	20,4±0,6	1,39
11	4,97±0,07	10,0±0	0,50	21,72±1,43	20,5±0,6	1,09	11,36±0,43	16,4±0,3	0,71
M±m	7,81±0,98	17,2±2,0	0,48±0,05	11,96±1,41	20,3±1,8	0,64±0,09	18,76±2,80	23,6±3,2	0,78±0,33

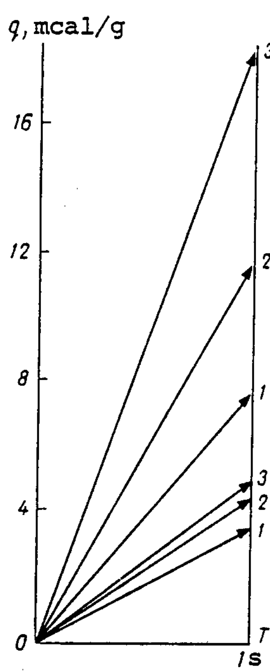


Figure 1.
Heat release rate per single contraction of isolated rat diaphragm under normal (1, 2, 3) and hyperoxic (1', 2', 3') conditions.

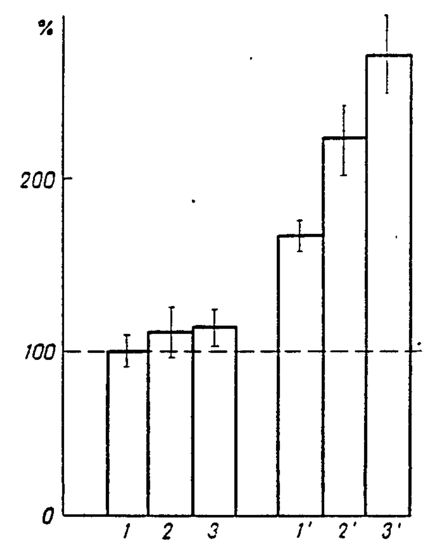
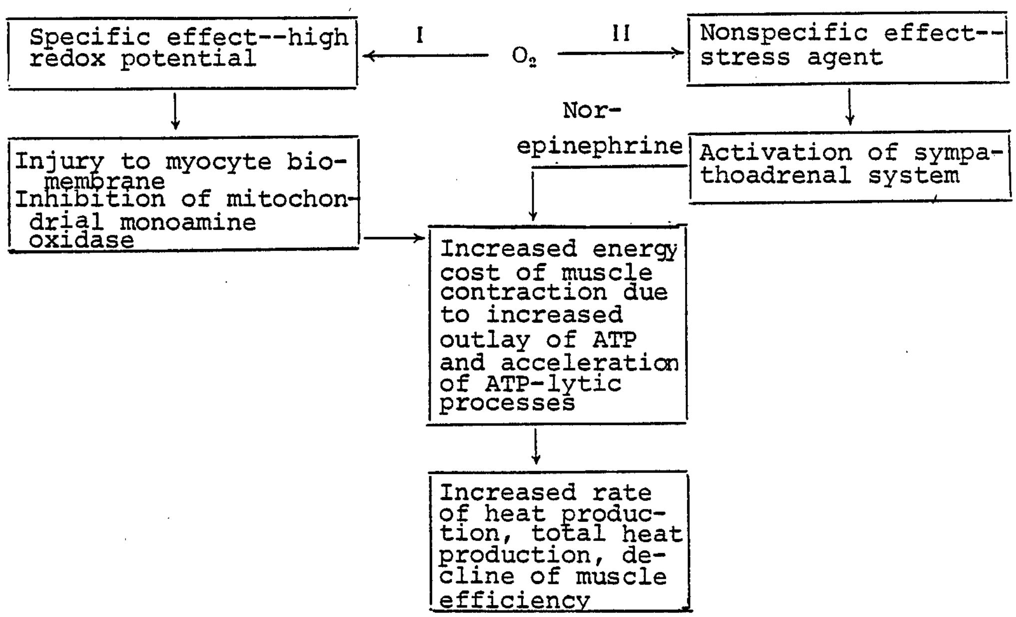


Figure 2.
Energy cost per gram isometric tension developed by muscle in single contraction (% of control). Designations are the same as in Figure 1

←Incubation of muscle preparations in three successive versions: saline (1) → NE (2) → ATP (3)

The results revealed that intensification of mechanical effectiveness of muscular contraction in the experimental group of animals was obtained at the price of disproportionately great increase in energy expended per unit muscualr contraction. How could this effect have been obtained? It is known that, in the presence of hyperoxia, tissue oxygen tension rises, which leads to an increase in number of free radicals as a result of intensified lipid peroxidation under the influence of high redox potential of oxygen. This leads to impairment of structure and function of biological membranes, as well as change in activity of enzymes localized in membranes. Inhibition of mitochondiral monoamine oxidase of the brain and liver was demonstrated [1] in the presence of hyperoxia, and it was particularly marked when experimental rat mitochondria were incubated with NE. Since the functional significance of monoamine oxidase under normal conditions consists of catabolism of catecholamines in tissues, it can be assumed that these protects cell energetics against the deleterious calorigenic effect of catecholamines.

Chart of increase in heat production during single muscular contraction under the influence of one-time 3-h use of oxygen



Note: I--direct route related to injury of cell membranes; II--indirect route related to activation of sympathoadrenal system.

Since many regulatory enzymes of catabolic and anabolic pathways are sensitive to AMP, ADP and ATP, D. E. Atkinson [7] advanced the principle, which is now generally recognized, that the rate of metabolic reactions is a function of energy charge of the adenylate ATP-ADP-AMP system, proceeding from which any acceleration of metabolic reactions is indicative of increase in energy charge of this system and leads to intensification of ATP-lytic processes in cells. Since the rate of heat production during muscular contraction reflects the rate of the corresponding metabolic reactions, acceleration of contractile heat

production under hyperoxic conditions is indicative of more intensive expenditure of energy for the contraction, on the one hand, and increase in the muscles' capacity for intensive dissociation of ATP under the influence of 99% oxygen, on the other hand. The fact demonstrated here, of a close relationship between rate of contractile heat production and ATP excess in the presence of NE under normal conditions, as well as the hypertrophied calorigenic effect of NE in the absence and presence of ATP with contraction of muscles from hyperoxic rats, apparently enable us to view NE as a specific factor that increases energy expenditure and heat production by stimulating ATP-lytic processes during contraction. In this aspect, NE can apparently be evaluated as a regulator of energy utilization by the functioning muscle cell. Under normal conditions, efficiency of muscular contraction is maximal (while energy cost of contraction is minimal), because the cell membrane reliably protects cell energetics against the excessive calorigenic effect of NE. However, in the presence of hyperoxia, due to the high redox potential of oxygen, the barrier function of biological membranes is attenuated and NE acts on the "exposed" adenylate system of the cell, stimulating intensification of ATP-lytic processes with predominant intensification of heat production in relation to force of muscular contraction. Ultimately, due to decreased efficiency of muscular contraction and increased heat production, intense muscular function under conditions of prolonged hyperoxygenation should lead to depletion of energy resources of the muscle cell. We can describe the signs of intensification of energy metabolism in muscles of animals submitted to brief hyperoxygenation proceeding from these considerations (see Chart).

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CLINICAL STUDIES

UDC: 629.78:616.1-008.1-06:616.12-008.331.1

CENTRAL HEMODYNAMIC PARAMETERS DURING DRY IMMERSION OF PATIENTS WITH BORDERLINE HYPERTENSION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 22 Apr 85) pp 73-74

[Article by V. I. Fomichev and To Nam Zeng]

[English abstract from source] Central hemodynamics parameters were measured in eight men, aged 45 to 55 years, with boundary arterial hypertension using a Soviet-made instrument and a dye (wofaverdin). Measurements were taken before "dry" immersion, 24 and 120 hours after the onset of "dry" immersion, and during recovery. Individual variations in the parameters of central hemodynamics to "dry" immersion were detected.

[Text] It has been reported that circulation volume does not change during 7-day immersion [3]. U. I. Balldin et al. [2] reported a 32% increase in circulation volume in 17 experiments on 3 healthy subjects using water immersion. At the same time, W. B. Hood et al. [4] failed to detect changes in these parameters with use of the Bremser-Ranke central hemodynamic method on healthy subjects submitted to dry immersion. A decrease in stroke and minute circulation volumes was found [1] during dry immersion. As we see, there is no agreement as to the condition of central hemodynamics of healthy subjects submitted to immersion.

Our objective here was to examine the parameters of central hemodynamics in healthy people and patients with borderline arterial hypertension submitted to dry immersion.

Methods

Central hemodynamic parameters were studied using the dye wofaverdin and a domestically manufactured apparatus with monochromatic ear sensor. Dry immersion was effected in a specially designed tank by the method in [1]. There were 10 men, 45-55 years of age, under observation, 2 of whom were in good health and 8 had borderline arterial hypertension. Central hemodynamic parameters (systolic and cardiac indexes, total peripheral resistance) were examined before immersion in the tank (baseline) and during "dry" immersion after 24 and 120 h in the tank and in the recovery period.

Results and Discussion

Baseline systolic and cardiac indexes were in the normal range in all subjects. As the stay in "dry" immersion progressed (after 24 and 120 h), individuals with borderline hypertension presented different directions of dynamic changes in systolic index. In the recovery period, the average systolic index corresponded to normal values. However, it differed from the baseline in some cases. As for mean systolic index, it showed a tendency toward rising by the 24th h of dry immersion (P>0.05), with persistence of the achieved level even on the 5th day of dry immersion. The systolic index reverted to the baseline in the recovery period (see Table).

Mean parameters of central hemodynamics in individuals with borderline hypertension at different stages of dry immersion

Parameter	Baseline	Immersion		Recovery
		24 h	120 h	
Cardiac index, ℓ/min/m^2	3.14±0.25	3.4±0.12	3.6±0.5	3.29±0.5
Systolic index, mℓ/m^2	52.0±10	57.6±8.5	57.4±7.5	50.7±6.5
Total peripheral resistance, ℓ/s·cm^{-5}	1498±51	1176±40.5*	1215±45.8*	1404±42.2

*$P < 0.05$.

After 24 h of dry immersion, healthy subjects presented some decline of systolic index, which differed insignificantly from the baseline on the 5th day and in the recovery period.

An analogous trend was demonstrable with respect to changes in cardiac index. Thus, the individual fluctuations were rather diverse in subjects with borderline hypertension after 24 h and up to the 5th day of dry immersion. In the recovery period it reverted to the baseline in all tested individuals. As for mean cardiac index, it showed a tendency toward rising by the 24th and 120th h of the experiment, but it conformed to the baseline in the recovery period.

In healthy subjects, the cardiac index dropped 24 h after immersion in the tank. It corresponded to the baseline on the 5th day and in the recovery period.

Baseline total peripheral resistance was above the top of the normal range in 3 subjects with borderline hypertension, whereas it dropped to normal after 24 h of dry immersion, holding at this level up to the 5th day of immersion. Peripheral resistance increased again in the recovery period, but remained below the baseline. On the 5th day of immersion, we observed some increase in total peripheral resistance in 2 patients, whereas no dynamics of this parameter were demonstrable in the rest of the subjects. In the recovery period, total peripheral resistance corresponded to the baseline. Three patients were an exception, showing positive dynamics of this parameter. Mean total peripheral resistance was reliably lower in individuals with borderline hypertension on the 2d and 5th days of dry immersion than before the experiment (P<0.05). In the recovery period this parameter reverted to the baseline (P>0.05).

The changes were somewhat different in healthy subjects: increase in total peripheral resistance by the 24th h of immersion followed by decline to less than the baseline on the 5th experimental day. In the recovery period, total peripheral resistance remained somewhat below the baseline in the healthy subjects.

Thus, in patients with borderline arterial hypertension there were individual changes in parameters of central hemodynamics during dry immersion. Changes in total peripheral resistance were demonstrated, which consisted of a decrease of this parameter during dry immersion.

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UDC: 616.12-008.331.1-056-092:612.131.17.014.47

RELATIONSHIP BETWEEN CONSTITUTIONAL DISTINCTIONS AND FUNCTIONAL CHARACTERISTICS OF THE CARDIOVASCULAR SYSTEM OF HEALTHY SUBJECTS AND PATIENTS WITH HYPERTENSION IN CLINOSTATIC AND ORTHOSTATIC POSITION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 22 Apr 85) pp 75-78

[Article by G. S. Belkaniya and V. A. Dartsmeliya]

[English abstract from source] This paper describes the results of a correlation analysis of the relationship between the basic parameters of central hemodynamics (arterial pressure, cardiac output, stroke volume, peripheral vascular resistance) and primary somatometric characteristics carried out in 90 healthy subjects and 62 patients with arterial hypertension in the clinostatic and orthostatic position. In the orthostatic position the correlation between somatometric characteristics and hemodynamic parameters increased significantly in comparison to the clinostatic position. It is assumed that orthostatic characteristics of circulation are an adequate phenotypical manifestation of the human genotype as a biped living being.

[Text] Even a brief review of development of conceptions of constitution shows that researchers have long since tried to find a link between body type and reactivity [4, 12, 13, 28]. At the present stage of this search, the conception was formed to the effect that morphological data alone are not sufficient to characterize the constitutional type, since somatometric and functional characteristics are closely linked. Many quantitative data have been accumulated to date concerning the link between constitution and metabolic distinctions and endocrine profile [2, 5, 8, 11, 16, 23, 29]. It is reported that these links are demonstrable only in the case of an increased load or in close to stress situations [1].

As for the correlation between body type and cardiovascular system parameters of healthy individuals, we can merely cite data to the effect that people with the hypersthenic type of constitution have a higher systolic arterial pressure (BP) [18, 24, 27, 28], there is more marked dilatation of arterioles in pyknics and athletes and constriction of arterioles in asthenics upon cold stimulation [25]. Hypoplasia of the cardiovascular system and the hypotensive syndrome are observed considerably more often in individuals with asthenic constitution [10]. In addition, there are data to the effect that the correlation between body type and BP at rest is not always clearly demonstrable [1, 23]. Thus, individuals with asthenic and normosthenic body types could not be differentiated

according to resting BP [7]. However, some tendency toward more marked orthostatic drop of BP was demonstrable in asthenics in orthostatic position. This finding is consistent with data to the effect that a positive correlation between height and mean BP ($r = 0.47$) is demonstrable in individuals with good orthostatic stability, whereas in cases of development of collapse a negative correlation is recorded between these parameters [26].

Analysis of the role of somatic constitution in etiology and pathogenesis of essential hypertension [14, 17] revealed that the relationship between these phenomena is far from unambiguous. In most studies, the aim was to demonstrate a correlation between BP level and incidence of essential hypertension, on the one hand, and general constitution type, on the other. In some studies, a link was found between arterial hypertension and the hypersthenic type of constitution, but in others it was not confirmed.

Thus, the data concerning the functional state of the cardiovascular system as a function of body type are sparse, contradictory and insufficient to comprehend the link between constitution and circulation in both healthy and sick humans. In view of the foregoing, our objective here was to establish a correlation between the somatometric constitutional characteristics and hemodynamic parameters in healthy subjects and individuals with arterial hypertension.

Methods

We conducted these studies on 90 healthy subjects and 62 with grades I and II arterial hypertension (AH) in the classification of WHO. All of the subjects were men 24 to 55 years of age.

We performed anthropometry on the subjects following the protocol for somatotypological identification developed at the Institute of Anthropology of Moscow State University [11]. In addition to the conventional features, three additional parameters were added to the system of somatometric characteristics: bottom "hydrostatic" size (BHS)--distance from cardiac beat to the floor (measured with the subject standing); top "hydrostatic" size (THS)--difference between height and BHS; hydrostatic index (HI)--ratio of THS to BHS.

Baseline functional parameters of the cardiovascular system were recorded on all subjects under basal metabolic conditions (in the morning, fasting) after 30 min at rest in horizontal position on a turntable. After this, the subjects were moved to orthostatic position (OP). The same parameters were recorded in the 1st, 5th, 10th, 15th and 20th min of OP.

Thoracic tetrapolar rheography was used to examine central hemodynamics [20], and indexed (scaled to body surface) values for stroke volume and cardiac output were used for analysis. Total peripheral vascular resistance was determined from the indicator of specific peripheral resistance. The rate of cardiac output at the initial phase of the ejection period, which reflected myocardial contractility, was evaluated according to amplitude of the differential rheogram (A_{dif}). The heart rate was determined from the rheogram, BP was measured by the Korotkov method. Up to five BP measurements were made at each interval considered.

Hemodynamic changes in OP were evaluated as percentage of CP [clinostatic position] parameters taken as 100%, according to averaged data for the transitory period (1-5 min) and period of stabilized hemodynamics (10-20 min). The obtained data were analyzed using nonparametric statistical methods. The digital data were processed on a computer using standard programs.

Results and Discussion

Comparative analysis revealed that patients with AH did not differ appreciably from healthy subjects with regard to somatotypological distinctions. The lack of differences is related, to some extent, to the relative homogeneity of physical development of the group studied, among whom variations of the muscular somatotype were encountered in most cases (Table 1). However, when we compared the different somatotypes among AH cases, we were impressed by the somewhat lesser representation of the purely muscular type (by 13%), muscular-thoracic type (7%), with increase in muscular-abdominal (by 9%), abdominal-muscular(6%) and abdominal with eurysomatic type (8%). In addition, the patients with AH weighed more and had a more marked development of body fat component, the average score for which was reliably higher than in healthy subjects (Table 2). Most probably, these differences are related to age-related distinctions of physical development, since the average age of AH cases was older than that of healthy individuals.

Table 1.
Relative (%) distribution of somatotypes among healthy and AH subjects

SOMATOTYPE	HEALTHY SUBJ	WITH AH
MUSCULAR	37	24
MUSCULAR ABDOMINAL	41	50
MUSCULAR THORACIC	11	4
UNDEFINED	3	4
ABDOMINAL MUSCULAR	2	8
THORACIC BROAD-BONED	6	—
ABDOMINAL	—	6
EURYSOMATIC	—	2
ASTHENIC	—	2

Table 2.
Somatometric characteristics of healthy and AH subjects

PARAMETER	HEALTHY SUBJECTS	PATIENTS WITH AH	P
AGE, YEARS	34,4±0,6	39,8±0,3	<0,01
WEIGHT, KG	76,3±1,1	82,7±2,1	<0,001
HEIGHT, CM	173,8±1,0	173,5±0,7	
MUSCLES, SCORE	2,96±0,01	2,98±0,07	
FAT, SCORE	2,94±0,02	3,43±0,08	<0,001
BONE, SCORE	3,39±0,01	3,34±0,08	
THS, CM	49,5±0,1	48,6±0,3	<0,05
BHS, CM	124,3±0,1	124,8±0,5	
HI, CM	0,398±0,001	0,389±0,004	<0,05
WEIGHT/HEIGHT	0,44	0,48	
MUSCLES/FAT	1,01	0,87	

The somatotypic homogeneity of healthy subjects and those with AH made it difficult to demonstrate a correlation between such an integral parameter as the somatotype and basic circulatory parameters. For this reason, we examined the correlation between hemodynamics and main somatometric constitutional features, rather than somatotype. The boundary value of the coefficient of correlation at $P<0.05$ constituted at least 0.3 for the sample under study.

As was to be expected, a rather close correlation was found between the main somatometric characteristics: a substantial correlation was established in 61% of the cases out of 100% possible links. In CP, the closest correlation in number of demonstrated links was noted between the central hemodynamic parameters considered, weight and body fat (52%), as well as HI (46%). The rest of the

somatometric characteristics (height, muscular and bone components of the body) showed the same correlation (33-37%) with parameters of the cardiovascular system. On the whole, the correlation between all of the considered somatometric and hemodynamic parameters at clinostatic rest constituted 39% (Table 3).

Table 3.
Comparative characteristics of CP (A) and OP (B) according to relative (% of maximum possible) number of links between somatometric and hemodynamic parameters

SOMATOMETRIC PARAMETER	HEALTHY SUBJECTS		WITH AH	
	A	B	A	B
WEIGHT	52	63	44	56
HEIGHT	37	52	46	42
MUSCLES	33	40	51	54
FAT	52	40	26	70
BONES	33	63	36	71
THS	23	37	36	60
BHS	37	73	40	50
HI	46	43	25	63
ENTIRE SOMATIC PROFILE	39	52*	38	58*

* $P<0,01$.

In OP, there was considerable intensification of correlation between the main somatometric constitutional characteristics and hemodynamic parameters, as compared to CP ($P<0.01$), and it reached 52% according to number of demonstrated correlations. It should be noted that patients with AH, like the healthy subjects, presented a distinct intensification of correlation between the main characteristics of somatotype and hemodynamic parameters in OP (see Table 3).

As had been shown previously [3, 9], the opposite relations were demonstrated between hemodynamic characteristics of circulation in CP and OP, which are based on qualitatively different distinctions of regulation. For this reason we performed a special comparative analysis of the direction of changes in correlations between somatotropic characteristics and hemodynamic parameters in OP as compared to CP. We took into consideration the lack of relationships or lack of changes in them, disappearance and intensification of correlations. We paid special attention to reversal of correlations. The analysis revealed that 45% of all demonstrated correlations between the parameters in question in CP changed to the opposite direction in OP. This serves as additional confirmation of the reality of demonstrated opposite relations between hemodynamic parameters in CP and OP, and stresses the practical importance of conditions under which functional characteristics of the cardiovascular system are measured.

The findings indicate that the closest correlations between somatotype and hemodynamic characteristics are formed in OP. In the presence of AH, basically an analogous correlation is noted between constitutional somatometric characteristics and hemodynamic parameters in CP and OP. This is apparently indicative of the fact that the same mechanisms are at the basis of the similar functional and morphological manifestations of the genotype in healthy subjects and those with AH.

The more marked correlation between somatotype and hemodynamic parameters serves as confirmation of the fact that circulation in OP, along with somatometric characteristics, is the most adequate phenotypic manifestation of the genotype of man as orthograde being. As we know, the somatotype is the morphological expression of the human genotype [16]. Our findings warrant the belief that

the functional characteristics of the main physiological systems, primarily circulation, in OP are the inherent functional manifestation of the species-specific genotype of man. The fact that about half the correlations between constitutional characteristics and hemodynamic parameters in OP change to the opposite direction in relation to CP is an important circumstance. Perhaps, the existing contradiction of information on correlation between constitutional characteristics and functional parameters of the cardiovascular system is related to expressly this circumstance. Traditionally, the state of clinostatic rest has been used to demonstrate the latter, while OP is the most constant physical condition of human activities [3, 6, 8, 15, 21, 22] and it determines the typical state of hemodynamics, rather than merely the reactive state. For this reason, in assessing baseline features of circulation, one should be governed primarily by the vertical, rather than horizontal, position. This must be adopted as the principal physiological norm of current status of hemodynamics in an orthograde being, such as man [3, 9, 19].

In view of the foregoing, the methodological meaning and practical implications of the anthropophysiological approach in human physiology and pathology are disclosed, in particular, for the study of circulation. The foundation of this approach (as reflected in its terminological definition) is that it directs itself primarily to the biological property of man as an orthograde being.

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UDC: 629.78:612-088.7:534.852

SPECIALIZED EQUIPMENT FOR MAGNETIC RECORDING OF PHYSIOLOGICAL DATA FOR EXPERIMENTS ABOARD BIOSATELLITES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 22 Jan 85) pp 79-80

[Article by V. S. Magedov and Yu. S. Koryakov]

[Text] Large volumes of scientific information have to be recorded when conducting automated physiological studies in biosatellites. The specificity of conditions of such investigations imposes size and weight restrictions on onboard equipment and precludes the possibility of servicing it during flight. The existing onboard magnetic recorders [3, 4] do not have a long enough continuous running time to record physiological data, and for this reason, it has become necessary to develop specialized magnetic recording equipment (MRE) that would service the purposes and conditions of long-term experiments aboard biosatellites. Such equipment must provide for many hours of continuous recording of physiological information within a specified band of recorded frequencies, and limited size and supply of magnetic tape.

We shall describe below the main theoretical premises that enabled us to develop a specialized MRE for continuous, long-term recording of physiological signals on magnetic tape. The method of frequency-modulated recording (FMR) was used in this equipment, since it permits maximum density of signal recording on the tape [2].

The duration of continuous recording on MRE within the specified band of recorded frequencies and possible stock of magnetic tape is limited only by the minimal permissible tape-feeding rate. This parameter is selected for recorders with FMR proceeding from the condition [1] that:

$$V \geqslant (1,5-2,0)\,\delta f_B, \qquad (1)$$

where f_B is the top frequency in the spectrum of the frequency-modulated signal (FMS) recorded on tape and δ is the width of the working gap in the magnetic reproducing head.

For technical reasons, the minimal value of parameter δ is usually 1-2 μm, while that of parameter f_B is determined by the equation:

$$f_B = F_B + \Delta f_M, \qquad (2)$$

where F_B is the top frequency in the spectrum of the input information signal and Δf_M is maximum width of the spectrum of FMS recorded on magnetic tape.

The physical meaning of equation (2) can be explained as follows. In the MRE, the carrier frequency of FMS (f_0) is selected so that the bottom range of its spectrum is higher than the top range of the spectrum of the recorded information signal (F_B). With reproduction, this rules out superposition of products of FMS demodulation on the information signal. Since the FMS spectrum is symmetrical in relation to f_0, the following condition must be satisfied:

$$f_0 \leqslant F_B + 0,5\Delta f_M, \tag{3}$$

hence, equation (2) is valid to assess the top range of the FMS spectrum recorded on tape.

Ye. I. Manayev [5] has shown that one can use the following function to assess the width of the FMS spectrum:

$$\Delta f = 2F\left(1 + \frac{mf_0}{F} + \sqrt{\frac{mf_0}{F}}\right), \tag{4}$$

where m is relative deviation of FMS carrier frequency. Substitution $F = F_B$ yields the evaluation for maximum spectrum width. The combined solution of equations (3) and (4) enabled us to obtain an analytical expression for calculation of f_0 when developing MRE with FMR:

$$f_0 \geqslant F_B \frac{\sqrt{m} + \sqrt{m + 8(1-m)}}{2(1-m)}. \tag{5}$$

Substituting in equation (5) the value of m in the range of 0.1 to 0.4, we shall have: $f_0 = (2.8 - 5.8)F_B$, $f_B = (4.6 - 10.6)F_B$. This coincides with the standards [2] recommended for MRE with FMR, and it confirms the validity of function (5).

The FMR equipment that was developed with consideration of the above equations can be arbitrarily referred to as a wide-use MRE. Such equipment is intended for recording signals with arbitrary shape of spectrum within the limits of the given bandwidth. At the same time, physiological signals are characterized by a spectrum that is attenuated in the region of high frequencies [6, 7]. When the specialized MRE was developed to record such signals, it was expected that longer continuous recording could be achieved in this case than with wide-use equipment.

A model of a normalized input signal in the frequency region to apply to the task of calculating the length of recording by the specialized MRE was selected in the following form:

$$S_n(x) = \begin{cases} 1 & a \leqslant x < a \\ \frac{1-x}{1-a} & a \leqslant x \leqslant 1 \end{cases}, \tag{6}$$

where $x = \frac{F}{F_B}$ is normalized frequency of input signal and $a = \frac{F_S}{F_B}$ is the normalized frequency of a section of the spectral characteristic. In this model, the value of parameter a should be chosen in such a way as to have the possible variations of amplitudes of spectral components for the entire aggregate of recorded physiological signals not to exceed the values limited at the top by function (6).

If we consider that, with modulation of carrier frequency by a signal such as (6) in the region of $x>a$ the actual deviation of frequency will diminish proportionately to change in amplitude of input signal, expression (3) can be rendered as:

$$\Delta f_n = \begin{cases} 2x\left(1+\frac{mn}{x}+\sqrt{\frac{mn}{x}}\right) & 0 \leqslant x < a \\ 2x\left(1+\frac{mn}{x}\cdot\frac{1-x}{1-a}+\right. & \\ \left.+\sqrt{\frac{mn}{x}\cdot\frac{1-x}{1-a}}\right) & a \leqslant x \leqslant 1 \end{cases}, \quad (7)$$

where $n=\frac{f_0}{F_B}$ – is normalized carrier frequency of FMS.

Analysis of (7) revealed that, for modulating signals described by model (6), evaluation of width of FMS band recorded on tape is at a maximum at frequency x equaling a. In this case, the expression for calculation of the normalized carrier frequency will have the following appearance:

$$n \geqslant \frac{\sqrt{ma}+\sqrt{ma+4(1-m)(1+a)}}{2(1-m)}. \quad (8)$$

Normalized values of carrier and top frequencies of FMS

m	a = 0,3	0,5	0,7	0,9	1,0
	Carrier frequency				
0,2	1,3	2,5	2,9	3,3	3,5
0,3	2,1	3,1	3,5	4,0	4,5
0,4	3,2	4,0	4,7	5,4	5,8
0,5	4,2	5,3	6,4	7,5	8,0
	Top frequency				
0,2	1,6	4,0	4,8	5,6	6,0
0,3	3,2	5,2	6,0	6,9	8,0
0,4	5,4	7,0	8,4	8,8	10,6
0,5	7,4	9,6	11,7	13,9	17,0

The Table lists normalized values for carrier and top FMS frequencies obtained by calculation for a series of values for parameters m and a. The values obtained for a = 1 correspond to a wide-use MRE. Since a<1 is valid for physiological signals, in developing the special MRE it was found possible to use lower values for n and, in accordance with expression (1), to set a slower tape-feeding rate than in wide-use equipment. These considerations were borne in mind in developing the Topol-D MRE, which is used aboard biosatellites of the Cosmos series.

Analysis of spectral characteristics of physiological signals that it was planned to record in experiments with monkeys enabled us to adopt a value of

0.3 for α, in the signal model (6). Guided by the nominal data listed in the Table, with the band of recorded frequencies set at 0 to 100 Hz and in accordance with (1), we find the minimal permissible tape feeding rate of 1.4 mm/s. In the Topol-D equipment, physiological signals are recorded and reproduced at the rate of 3 mm/s.

The Topol-D MRE includes a ground-based Topol-DV recorder and onboard Topol-D3 recorder. The latter, the dimensions of which are 280×250×160 mm, provides for continuous recording of physiological signals for at least 68 h on magnetic tape that is 27 μm thick. The equipment has 11 recording channels with a signal/noise ratio no worse than 40 dB. Signals can be recorded and reproduced under laboratory conditions with the ground-based recording device, and it can also reproduce information recorded on the Topol-D3 onboard recorder. Topol-DV recorder has two tape-feeding speeds, 3 mm/s and 3 cm/s, and the band of frequencies recorded at the higher speed is in the range of 0 to 1000 Hz.

In comparing the features of Topol-D equipment and the equipment described in [3], it should be noted that, other conditions being equal (band of recorded frequencies and dynamic range), consideration of actual characteristics of physiological signals made it possible to reduce the tape-feeding rate to two-thirds in the specialized recorder.

Topol-D equipment was used with success to record physiological information aboard Cosmos-936, Cosmos-1129 and Cosmos-1514.

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UDC: 612.223-008.1+613.155.3-074

EVALUATION OF METHOD FOR COLLECTING AND CONCENTRATING ORGANIC TRACE IMPURITIES IN AIR

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 11 Mar 85) pp 81-83

[Article by O. A. Sukhorukov, M. V. Azarova, and B. L. Avetisyants]

[Text] At the present time, in gas chromatography the limit of sensitivity of ionization detectors has been virtually reached, and further raising of the range of detection of trace impurities may proceed either in the direction of increasing the amount of trace impurities per unit sample volume fed to the input of an instrument, or by means of more efficient conversion of information in the course of measurement and data processing at different stages of analysis [1-3]. Concentration is one of the ways of increasing information per unit sample volume. However, in the course of concentration there could be worsening of metrological characteristics of the analytical measurement process, and there could be increased loss of material due to irreversible adsorption on sorbents and interaction of impurities with one another. Then it becomes necessary to additionally purify the gases and reagents used [6]. All this compels us to investigate more thoroughly the different stages of analysis of trace impurities in the method needed to examine contaminants in the environment and room air.

We evaluated here methods of collecting and concentrating trace impurities from the air using a standard method of preparing them (diffusion through a capillary) [1].

Methods

The method of diffusion through a capillary was used to obtain low concentrations of organic substances [1]. Let us briefly discuss the theory of this method, since it has not been described in sufficient detail in the literature. We have a capillary with length l and section S, at one end of which (with $l = 0$) vapor pressure of standard substance P_0 is maintained. Let us examine a linear problem, in which concentration c is a function of length x and time t.

The equation for diffusion of a standard substance through a capillary can be written out as follows:

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2};\quad 0 \leqslant x \leqslant l, \tag{1}$$

with boundary conditions:

$$x = 0;\ c = c_0; \tag{2}$$

$$x = l;\ DS\frac{\partial c}{\partial x} = v \cdot c. \tag{3}$$

Condition (3) means that the flow of substance at the top end of the capillary is carried off by the flow of inert gas at velocity v.

Concentrations at the top end of the capillary are:

$$c = c_0\left[\frac{D \cdot S}{v \cdot l}\right] = \frac{P_0}{RT}\left[\frac{D \cdot S}{v \cdot l}\right]. \tag{4}$$

Formula (4) was used to calculate concentrations of different substances (Table 1). To prepare low concentrations of trace contaminants, we used a capillary 20 cm long with inside diameter of 0.52 mm; air was pumped through at the rate of 146 cm^3/min.

As an example, let us evaluate the relative error in calculating the concentration of benzene in the diffusion system using formula (4) after differentiating it for all parameters under the following conditions: L_C = 20 cm, S = $2 \cdot 10^{-3}$ cm^2, v = 0.125 cm^3/s, P_0 = 75.2 mm Hg, t = 20°C, $D_{C_6H_6-He}$ = 0.372 cm^2/s, R = 0.082 ℓ•atm/degree•mol, and M = 78.11.

The margin of error in determination of P_0 did not exceed 1 mm Hg: ΔD ~ 10%, ΔS = $7.85 \cdot 10^{-5}$ cm^2, ΔL = 0.1 cm, Δt = 0.1°C and Δv = 0.0033 cm/s. Under these conditions the error in calculating concentrations with formula (4) would be: Δc_{tot} = $1.4131 \cdot 10^{-5}$. In determining the concentration of benzene, total relative error is less than 1%.

To assess the methods of collecting and concentrating organic trace impurities from air, we used the system illustrated in Figure 1. It consisted of 4 metal traps with inside diameter of 10 mm and volume of 7.85 cm^3. The first trap was empty and cooled with ice at 0°C; the second had 5 cm^3 chromosorb [kieselguhr] WAW 60/80 with 10% emulphor* ON-870 to trap alcohols or 5 cm^3 chromosorb WAW-DMCS 60/80 with 5% dexyl-300 to trap ketones, aromatic and saturated hydrocarbons. The third and fourth traps were filled with 3.5 cm^3 silochrome C = 80 (0.38-0.49). The fourth was used to check completeness of trapping agents that sorb poorly (for example, hydrocarbons). The second, third and fourth traps were cooled with dry ice (-78°C).

Before starting the experiment, all of the traps were flushed with helium at a temperature of 270°C (the empty traps with silochrome and dexyl) and 180°C (traps with emulfor) for 6 h. The traps were placed in a Dewar flask with ice and room air was blown through the diffusion system for 2 h at the rate of 145-150 cm^3/min to establish equilibrium. Instead of traps, a 1-m copper tube with inside diameter of 2 mm, was inserted as resistance. Upon termination of the stabilization period, air pumping was stopped and the diffusion system

*Latex stabilizer and emulsifier.

was connected in the appropriate manner to the prepared system of traps, system for air purification and sampling aspirator. The rate of pumping gas through the system was set at 146-152 cm^3/min, and 10 ℓ gas were pumped through the traps. Then the aspirator was turned off, the traps sealed in refrigerators and stored in dry ice until ready for analysis.

Table 1.
Vapor pressure of tested substances (at t = 0-5°C) and their diffusion coefficients in air in the temperature range of 0-20°C, and concentrations (mg/ℓ) at air velocity of 146 cm^3/min [2, 7]

Substance	P_0, mm Hg	$D_{0-20°}$, cm^2/s	$C_{nom} \cdot 10^3$ mg/ℓ (v = 146 cm^3/min)
Benzene	30,877	0,082	0,492
Toluene	8,044	0,075	0,138
p-Xylene	1,237	0,070	0,023
Heptane	17,253	0,065	0,279
Octane	3,487	0,053	0,053
Nonane	1,200	0,045	0,017
Acetone	81,450	0,120	1,413
Methyl ethyl ketone	30,200	0,104	0,532
Butanol-2	3,100	0,072	0,042
Ethanol	12,300	0,112	0,163
Propanol-1	3,700	0,086	0,049

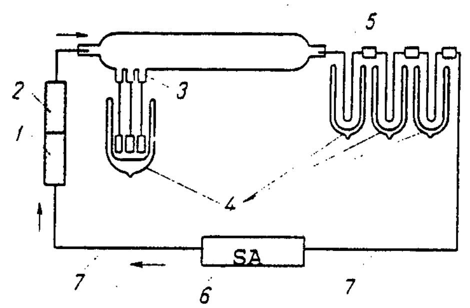

Figure 1.
Drawing of device for trapping trace impurities
1,2) air drying and purification with silica gel and activated charcoal
3) diffusion device to obtain low concentrations of organic impurities
4) Dewar flasks for coolants
5) system of traps
6) gas sampling aspirator [SA]
7) connective tubes

Trace impurities from the traps were identified on a Hewlett-Packard 5880A chromatograph with ionization-flame detector. For analysis, we used glass columns 3 m in length, with inside diameter of 2 mm, and the following phases: 10% PEG [polyethylene glycol]-4000 on WAW 60/80 chromosorb treated with 4% KOH; 10% rheoplex 400 on WAW 60/80 chromosorb; 0.2% PEG-1500 on carbopack C. Samples were collected with a 250 μℓ syringe from traps heated to the following temperatures: 245-248°C for the empty trap and the one with silochrome and dexyl, 172-176°C for the trap with emulphor. Argon was used as the gas carrier; the column thermostat temperature was 50°C for hydrocarbons and 80°C for all other substances.

Figures 2 and 3 illustrate examples of chromatograms.

Results and Discussion

Table 2 lists the experimental results processed by methods of mathematical statistics [4, 5].

Let us assess the margin of error in measuring concentrations of the substances studied with change in room temperature and rate of pumping air through the

Table 2. Experimental results processed by mathematical statistical methods [4, 5]

Substance	$c_{nom} \cdot 10^3$, mg/ℓ	$c_{exp} \cdot 10^3$, mg/ℓ	K_{tr}	n	σ_i	$\sigma_{\bar{x}} = \frac{\sigma_i}{\sqrt{n}}$	$\bar{x} \pm z \frac{\sigma_i}{\sqrt{n}}$	$\frac{\sigma_{\bar{x}} \cdot 100}{\bar{x}}$, %
Ethanol	0,163	0,117	0,72	5	0,083	0,037	0,117±0,072	31
Propanol-1	0,049	0,027	0,55	5	0,009	0,004	0,027±0,007	14
Butanol-2	0,042	0,017	0,40	8	0,007	0,002	0,017±0,004	14
Acetone	1,413	0,194	0,14	8	0,121	0,043	0,194±0,084	22
Methyl ethyl ketone	0,532	0,094	0,18	8	0,046	0,016	0,094±0,031	17
Benzene	0,492	0,442	0,90	8	0,165	0,060	0,442±0,115	13
Toluene	0,138	0,135	0,98	6	0,067	0,027	0,135±0,052	20
p-Xylene	0,023	0,025	1,00	8	0,014	0,005	0,025±0,009	19
n-Heptane	0,279	0,235	0,84	10	0,054	0,017	0,235±0,033	7
n-Octane	0,053	0,043	0,81	10	0,018	0,006	0,043±0,011	13
n-Nonane	0,017	0,010	0,59	10	0,006	0,002	0,010±0,003	18

Key: c_{nom}, c_{exp}) estimated [2, 7] and obtained concentrations of tested substances

K_{tr}) coefficient of trapping, which equals c_{exp}/c_{nom}

n) volume of sample in assessing $\bar{x} = c_{nom}$

σ_i) standard deviation for $\bar{x}$

$\sigma_{\bar{x}}$) standard deviation of arithmetic mean (or mean error of mean)

$\bar{x} \pm z \frac{\sigma_i}{\sqrt{n}}$ confidence interval for mean value of c_{exp} out of normally distributed general set (the value of z is taken at 95% statistical reliability)

$\frac{\sigma_{\bar{x}} \cdot 100}{\bar{x}}$ standard deviation (% of arithmetic mean)

system of traps. When measuring concentrations of benzene, toluene and *p*-xylene, room temperature varied from 16 to 22°C (mean 19.7°C), which yields an error of ±4.9% for 9 experiments. The margin of error in aspiration of air when pumping it through the system of traps ranges from 6% when the traps freeze to 0.5% (ordinarily).

Standard deviation of input of benzene specimen with a sampling of 155 inputs equals 0.455, which yields a 1.51% margin of input error. For smaller samples (according to classes of substances), the errors were as follows: 3.2% for ketones (n = 18), 2.5% for aromatic hydrocarbons (n = 23), 2.4% for *n*-hydrocarbons (n = 22) and 2.1% for alcohols (n = 22).

Table 2 shows that the margin of error in determining concentrations constituted 7-31%, which is obviously higher than the error in sample input, temperature fluctuations and rate of pumping air through the traps. It was observed that the conditions under which the traps are cooled, in particular, degree of shrinkage of coolant, have a significant influence on the value of c_{exp}.

The lowest error was obtained in trapping trace amounts of saturated and aromatic hydrocarbons, and the best output coefficient was also obtained

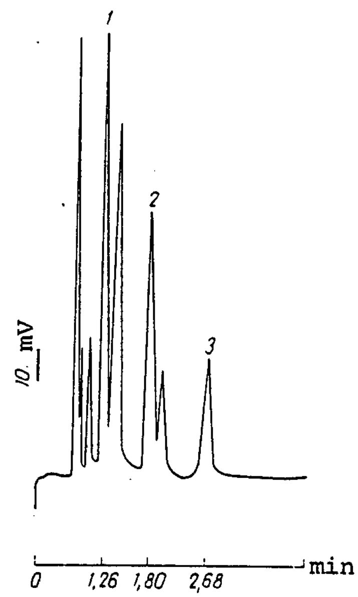

Figure 2.
Chromatogram of aromatic hydrocarbons; column--10% rheoplex-400 on chromosorb WAW 60/80 mesh at 80°C
1) benzene 2) toluene 3) xylene
Here and in Figure 3: x-axis, time (min)

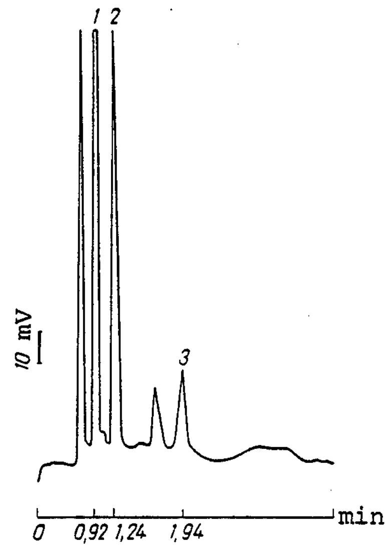

Figure 3.
Chromatogram of saturated hydrocarbons; column--10% rheoplex-400 on chromosorb WAW 60/80 mesh at 50°C
1) heptane 2) octane 3) nonane

for them (c_{exp}/c_{nom}), which equaled 0.8-1.0. We observed considerable scatter of results for alcohols, which could be attributed to their dissolution in the film of water, which is always present in the air in the form of vapors.

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BRIEF REPORTS

UDC: 629.78:612.43/.45.018

ENDOCRINE STATUS OF COSMONAUTS FOLLOWING LONG-TERM SPACE MISSIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 3 Jan 85) pp 84-86

[Article by N. F. Kalita and R. A. Tigranyan]

[Text] Spaceflights are associated with a set of stress factors that affect many systems of the body, in particular the endocrine system [3]. The studies conducted to date yielded some information concerning the endocrine status of cosmonauts during and after spaceflights. At the same time, in spite of good physical training and conditioning of cosmonauts, individual changes may occur in the reactions of each of them in response to spaceflight factors, which are related to different characteristics, including psychological and age-related ones. For this reason, it is rather important to study the endocrine status of cosmonauts, since this would deepen our understanding of changes that take place in the body.

Our objective here was to examine the levels of a number of hormonal and biologically active compounds in cosmonauts who had participated in long-term (73-185 days) spaceflights and to demonstrate stressor reactions in the acute period of readaptation to earth's gravity (Footnote 1)(V. M. Ivanov (insulin (STH), B. V. Afonin (aldosterone, renin), E. A. Pavlova and Ye. V. Kolchina (cyclic nucleotides, prostaglandins) participated in these studies).

Methods

Venous blood and 24-h urine were taken for analysis. Blood was drawn and 24-h urine collected 30 days before the flight. In addition, 24-h urine specimens were collected 5-3 days before launching the spacecraft. Postflight blood tests were made on the 1st and 7th days after landing; 24-h urine was collected on the day of landing (0 day) and for the next 7 days.

Radioimmune analysis (RIA) was used to measure the following in the cosmonauts' blood: concentration of ACTH, cortisol (F), aldosterone, thyroxine (T_4), triiodothyronine (T_3), testosterone, somatotropic hormone (STH), cyclic adenosine monophosphate (cAMP) and guanosine monophosphate (cGMP), prostaglandins (PG) referable to pressor ($PGF_{2}\alpha$) and depressor (PGA+E) groups, as well as activity of renin, insulin and thyrotropic hormone (TTH). Aldosterone content in urine was measured by the RIA method and excretion of total 17-hydroxycorticosteroids (17-HCS) by the reaction with phenylhydrazine [5].

Preliminary review of the results obtained for each of the long-term space missions failed to reveal a clear enough correlation between changes in the parameters tested and flight duration, and for this reason we deemed it possible to combine data on all missions for our analysis. The material obtained from 10 cosmonauts was submitted to statistical processing with use of Student's *t* criterion.

Results and Discussion

The data obtained on the cosmonauts revealed that the preflight period is associated with a change in proportion of pressor and depressor PG in the direction of prevalence of depressor PG (Table 1), as well as excretion of total 17-HCS which is close to the top of the normal range, particularly in the prelaunch period (Table 2), which is inherent in emotional stress [6]. In our opinion, such changes may be related not only to the unique life style of cosmonauts, but the emotional tension before flights. The other parameters were within the normal range in the preflight and prelaunch periods.

Table 1. Hormone and biologically active compound levels in blood of cosmonauts (M±m)

Parameter	30 days preflight	Postflight days	
		1	7
ACTH, pg/mℓ	45,22±9,68	50,00±10,05	71,33±17,22
Cortisol, μg%	16,04±1,21	18,46±2,56	15,33±1,31
Aldosterone, pg/mℓ	67,1±16,4	18,8±5,3*	68,9±7,4
Renin, ng/mℓ·h	3,16±0,38	2,26±0,23*	2,37±0,31
Insulin, μU/mℓ	17,00±0,82	22,17±1,10*	21,10±1,94
TTH, μU/mℓ	1,87±0,11	2,04±0,12	1,74±0,45
T_4, μg%	6,61±0,42	8,86±0,25*	6,96±0,53
T_3, ng%	158,9±9,10	175,9±9,89	143,1±10,11
STH, ng/mℓ	1,88±0,34	1,78±0,44	1,26±0,44
Testosterone, ng%	640,0±46,1	537,0±20,9*	555,0±21,6
cAMP, pmol/mℓ	17,5±3,9	20,7±4,37	15,7±2,3
cGMP, pmol/mℓ	3,81±1,06	4,86±1,18	5,95±1,14
PGF_2-α, ng/mℓ	1,08±0,16	0,68±0,15	0,59±0,16*
PGA+E, ng/mℓ	3,81±0,81	1,41±0,38*	0,82±0,22*

Note: Here and in Table 2, the asterisk indicates reliable differences from preflight values.

Table 2. Excretion of steroid hormones in urine of cosmonauts (M±m)

Parameter	Preflt, days		Postflight days							
	30	5—3	0	1	2	3	4	5	6	7
17-HCS, total, mg/day	6,81 ±1,80	7,22 ±0,91	7,15 ±1,80	6,70 ±1,66	6,21 ±2,00	7,51 ±1,96	8,28 ±0,89	7,55 ±1,00	6,56 ±1,04	5,87 ±1,52
Aldosterone, μg/day	14,4 ±1,3	13,3 ±2,0	17,9 ±3,4	29,9 ±5,3*	20,8 ±4,4	21,3 ±4,7	17,7 ±4,1	22,5 ±3,0*	25,1 ±3,8*	—

In the postflight period, the cosmonauts failed to show reliable changes in statistically mean values for parameters characterizing functional activity of the hypothalamus-pituitary-adrenal cortex-ACTH system, F, total 17-HCS (see Tables 1 and 2), which was apparently related to the rather wide individual scatter of parameters studied. It should be noted that excretion of total 17-HCS on the 3d-5th postflight days did not differ reliably from preflight values, exceeding the top of the normal range (see Table 2). This may be indicative of activation of glucocorticoid function of the adrenals. In addition, individual analysis of the findings revealed that all cosmonauts presented significant increase in total 17-HCS excretion after completing 73-, 96- and 185-day spaceflights, particularly on the 3d-5th postflight days [3]. The highest values for this parameter were found in cosmonauts who participated in the 96- and 185-day missions.

On the first postflight day, there was reliable decrease in plasma renin activity and blood aldosterone level (see Table 1), in the presence of significant increase in aldosterone excretion in urine (see Table 2). The decrease in plasma renin activity could apparently be related to the reverse inhibitory effect of aldosterone, the biological activity of which was considerably increased following long-term space missions, which is confirmed by the more marked retention of sodium and fluid in this period [1].

We cannot rule out the possibility that the drop in blood aldosterone level on the 1st day of the postflight period could be related to diminished plasma renin activity. However, the low blood aldosterone concentration with concurrent increase in its excretion may be attributable to increased metabolism of this hormone in the body, since functional activity of the liver apparently diminishes on the 1st postflight day, as indicated by the decrease in activity of blood alanine aminotransferase [3].

At the same time the set of preventive measures undertaken by the crews during long-term missions led to rather rapid restoration of normal correlations in the reinin-angiotensin-aldosterone system. By the 7th postflight day, blood aldosterone concentration differed insignificantly from preflight values, while plasma renin activity continued to be lower than the preflight level (however, this difference was unreliable; see Table 1).

On the 1st day of the period of readjustment to earth's gravity there was a reliable elevation of blood insulin level, which exceeded the top of the normal range (see Table 1). In the case of 7-day missions, the increase in insulin concentration was within the normal range [2]. In all probability, the increase in blood insulin concentration could have been a reaction to increased glucose concentration in these cosmonauts [3], and indicative of tension, since this hormone, along with other indicators of stress, mediates the effect of catecholamines.

Unlike short-term missions [2], in long-term flights the cosmonauts presented a reliable increase in blood T_4 content, and there was a tendency toward increase in activity of TTH and concentration of T_3 (see Table 1). Analogous changes in parameters characterizing the functional activity of the pituitary-thyroid system and blood insulin level were found in American astronauts after flights aboard the Skylab orbital station [4].

There was a reliable decline of blood testosterone level on the 1st day after long-term flights, unlike short ones [2] (see Table 1). This could be indicative of a stress state.

Elevation of insulin and T_4 levels, and decrease in blood testosterone concentration could have caused accumulation of triglycerides in blood, which was noted in these cosmonauts [3].

In the postflight period, blood PG of both groups decreased at both tested times in the cosmonauts, this being more marked for depressor PG (A+E), so that there was prevalence of the PG pressor group over their physiological antagonists. PGA+E level was below the bottom of the normal range (see Table 1). Such changes are apparently a compensatory reaction aimed at increasing vascular tonus and preventing orthostatic instability, and they are typical of emotional stress [6].

It should be noted that the changes in STH and cyclic nucleotides in the cosmonauts' blood were not reliable at both postflight testing times (see Table 1).

Thus, the period of readaptation to earth's gravity following long-term space missions was associated with a moderate tension reaction, as indicated by increased glucocorticoid function of the adrenals, increased activity of β cells of the islet system of the pancreas and change in proportion of pressor and depressor PG.

The changes in hormonal status observed after the cosmonauts returned to earth's gravity were soon compensated, which characterizes them as being reversible, adaptive reactions to spaceflight factors and the recovery period, and indicates that the cosmonauts were highly conditioned and well-prepared for the flights. However, at the present time we do not know what the ultimate consequences of these changes would be if spaceflights are extended to longer periods of time.

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UDC: 612.172.2-06:612.763]-019:599.824

ORTHOSTATIC CARDIAC RHYTHM RESPONSE IN WAKING MACACA MULATTA MONKEYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 27 Dec 83) pp 86-88

[Article by M. D. Goldovskaya, V. P. Melnichenko, and B. S. Kulayev]

[Text] There are only isolated publications in the literature that describe orthostatic reactions of heart rhythm in waking monkeys [1]. The nature of the responses in those investigations could have been largely determined by an unstable heart rhythm associated with motor excitement of immobilized monkeys. Our objective here was to evaluate the orthostatic cardiac rhythm response in waking monkeys with consideration of this factor.

Methods

We examined 10 clinically healthy male Macaca mulatta (Macaca rhesus) weighing 4.5-5 kg. They were tested on a turntable, the monkeys being in supine position at first. Only one test was performed with one animal on the day of the examination. To diminish effects that would excite the animal, we used a soft immobilization system and a special "saddle," on which the monkey could rest its buttock callosities. Electrodes were chronically implanted in one of the Nehb leads. The animals were isolated in a separate room, into which the experimenter came only to turn the table platform. Head movements by the monkey were restricted by means of an ample-sized mesh helmet tied to the table platform. The monkeys were placed and immobilized on the table after being given superficial anesthesia (4.0-4.5 mg/kg ketamine intramuscularly). The tests were started 2-2.5 h after finishing the immobilization procedure, when the usual behavioral and orienting reactions were restored. A television camera was used for continuous monitoring of the monkey's behavior. The investigation consisted of a baseline period (horizontal position for 15 min) and orthostatic factor (+75°, 15 min). The ECG was recorded on chart strips every 3 min, and we determined the heart rate (HR), counting the number of cardiac cycles per 20 s. The ECG tracing segments that were preceded by absence of myographic induction on the strip for 30 s or more, such a state lasting for 10 s or more after counting the HR, were considered "quiet." In a separate (control) series of experiments (7 orthostatic tests on 6 animals), ketamine was injected intramuscularly in an anesthetizing dosage (10 mg/kg) to the monkey immediately after being immobilized on the table, and 10 min later it was moved to orthostatic position. In view of the very rapid elimination of the effect of ketamine, we used relatively brief (5 min) orthostatic loads.

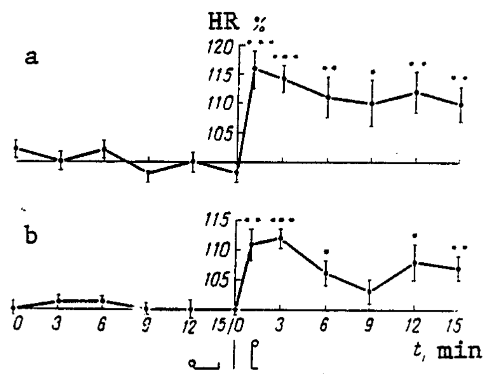
Monkeys' heart rate in horizontal and orthostatic positions

Position	Parameter	Monkey No 1 I	1 II	1 III	2 I	2 II	2 III	3 I	3 II	4 I	4 II	5 I	6 I	7 I
Horizontal	X_{max}	204*	201	207*	180	162	177	201*	204*	174	192*	228*	207	234*
	X_{min}	168	192	195	168	150	153	180	180	144	156	192	186	219
	Δx	36	9	12	12	8	24	21	24	30	36	30	21	15
	M	183,6	195,0	200,0	173,3	155,4	165,6	190,0	189,0	159,6	170,0	211,5	198,0	224,0
	m	7,9	1,7	2,1	2,6	2,8	4,3	2,9	3,6	4,1	5,5	5,3	3,6	2,3
Head up	X_{max}	210*	222*	243*	234*	198*	201*	231*	207*	192*	222*	228*	270*	243*
	X_{min}	183	204	207	189	174	162	192	177	174	168	195	252	234
	Δx	27	18	36	45	24	39	39	30	18	54	33	18	9
	M	197,4	214,8	226,0	213,0	187,8	185,0	217,5	192,5	180,0	184,0	209,0	261,5	238,5
	m	5,3	2,2	5,9	8,6	4,2	6,3	5,6	4,4	3,3	9,0	5,0	2,6	1,7

Notes: I-III--orthostatic tests; X_{max}, X_{min}, Δx--maximum, minimum HR and difference betwen them, respectively. An asterisk shows that the parameters were recorded for monkeys displaying motor excitement.

Results and Discussion

As compared to the baseline, in orthostatic position the HR increased by a mean of 12.1% in all tests (see Table). In the 1st min of the orthostatic test HR exceeded the baseline by a mean of 16.4%, then decreased somewhat; however, it remained above the baseline level with statistical reliability throughout the orthostatic period (see Figure). If, however, we considered only the ECG tracings that were not associated with motor reactions (in both the baseline period and orthostatic position), the increase in HR was less marked in orthostatic position, by a mean of 7.6% (see Figure). As can be seen from the figure, in this case HR rose in orthostatic position. Then (3d-9th min of test) there was attenuation of the acceleration reaction of HR and the difference from the baseline became unreliable. Subsequently, in the 9th-15th min of the orthostatic test, HR again increased. Thus, the dynamics of the orthostatic response of heart rhythm demonstrated without motor excitement of the monkey was phasic in structure.



Dynamics of monkeys' heart rhythm during orthostatic tests (% of stable level in horizontal position); x-axis, time (min); y-axis, mean HR (%); vertical lines--standard errors of means

a) values obtained with consideration of all recorded HR
b) same without motor restlessness

*P<0.05 **P<0.01 ***P<0.001

With respect to testing waking animals, the question arises as to whether the HR changes demonstrated in orthostatic position reflect the influence on heart rhythm of psychoemotional excitation associated with moving the animal to head-up position and remaining in that position. Control orthostatic tests were performed on anesthetized monkeys who had no psychoemotional responses. After administration of an anesthetizing dose of ketamine, the baseline heart rate (180-249/min) slowed down and reached a stable level (159-207/min) in 8-10 min. This individual level was taken as 100%. In the 1st min of orthostatic position the heart rate increased by a mean of 7.1±2.9% ($P<0.05$), changing insignificantly thereafter throughout the 5-min test period (HR was recorded every minute). This finding enables us to conclude that orthostatic changes in HR in waking monkeys cannot be interpreted as an expression of an exclusively psychoemotional reaction; they also reflect the systemic reaction to a gravity factor.

A pulse of 80-90/min corresponds to psychoemotional comfort in monkeys [4]. In our cases, HR exceeded this level appreciably in the baseline period, in both waking and anesthetized monkeys. Since the heart rate is a sensitive indicator of emotional state and state of autonomic regulatory systems [2], it can be assumed that we tested orthostatic reactions on animals that presented elevated (as compared to calm psychoemotional status) baseline activity of sympathetic centers of heart rate regulation.

In waking monkeys, this could be due to stressful factors which were present, in spite of the steps taken to prevent excitement, and in anesthetized animals it could be due to the effect of ketamine on the system of regulating circulation. Since orthostatic reactivity of circulation is largely determined by the functional state of regulatory mechanisms [3], we cannot rule out the possibility that the nature of the orthostatic HR response in our cases is a function of the signs of heightened baseline activity of sympathetic branches of the autonomic nervous system.

Thus, it should be noted that analysis of HR in the presence of and without motor excitement of monkeys enabled us to demonstrate a distinction in the cardiac response to the orthostatic test, which consisted of phasic dynamics.

The results of this investigation were used to develop methods of conducting postural tests on monkeys within the limits of programs of preflight and postflight examination in conducting flight experiments aboard Cosmos-1514 biosatellite.

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CURRENT EVENTS AND INFORMATION

UDC: 629.78:61+574.68+613.693]:
061.3(47+57)"1985"

PROBLEMS OF AVIATION AND SPACE MEDICINE, BIOLOGY AND PSYCHOLOGY DISCUSSED AT FIFTEENTH GAGARIN SCIENTIFIC LECTURES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (manuscript received 27 Sep 85) pp 88-94

[Article by G. S. Ratner]

[Text] The 15th Gagarin Scientific Lecture Series took place from 1 to 10 April 1985. The lectures were dedicated to the 40th anniversary of the Soviet nation's victory in the Great Patriotic War of 1941-1945 and the 25th anniversary of the Center for Cosmonaut Training. The plenary sessions convened in the Hall of Columns in the House of the Unions in the town of Zvezdnyy and at the Institute of Problems of Mechanics of the USSR Academy of Sciences. At the first session, one of the papers was delivered by Prof A. D. Yegorov under the title of "Biomedical Problems of Long-Term Spaceflights." It dealt with analysis of biological mechanisms of effects of weightlessness and other spaceflight factors on man on the basis of summarization of the results of investigations and experience with spaceflights. The demonstrated patterns and recommendations developed on their basis made it possible to achieve records with regard to duration of human active performance in space. The speaker also demonstrated the promising routes of future studies, including those related to solving problems of faster adaptation to weightlessness and recovery after flights.

Two papers were delivered at the general meeting of the section, "Problems of Aviation and Space Medicine and Psychology," chaired by Academician O. G. Gazenko. USSR Cosmonaut-Pilot O. Yu. Atkov, candidate of medical sciences, told about the studies he conducted during the 237-day flight aboard the Salyut-7 orbital station. In all, more than 300 biomedical experiments referable to 34 projects were conducted. The main items in the program were: in-depth studies of the cardiovascular system using the Soviet-made Argument ultrasound system and French Echograph; investigation of functions and interaction of vestibular and visual analyzers and mechanisms of onset of motion sickness; biochemical tests of blood and urine.

Use of more intensive load exercises on a combined simulator and bicycle ergometer, as well as new functional tests, were the distinctive feature of preventive measures.

The crew retained a high work capacity during the flight, and as a result the entire program was successfully fulfilled.

The studies conducted aboard the orbital complex suggest that the human body experiences at least two stages of adaptation to weightlessness--acute stage and stage of acute adaptation. The acute stage lasts 2-3 days to 1 week. In the first hours of flight there is an increase in venous return of blood with its redistribution primarily to the upper half of the trunk. This leads to alteration of vascular and cardiac reflexes, as a result of which there is moderate decline of arterial pressure and some tachycardia. The Henry-Gauer reflex appears, which ultimately leads to decrease in circulating blood volume. At the same stage, there is adaptation of the vestibular system.

Then the stage of stable adaptation is formed, the important elements of which are balanced redistribution and deposition of part of the blood, as well as elimination of the required amount of fluid from the body. Thus, a new physiological equilibrium is established.

No pathological changes were demonstrable in crew members in the course of the 237-day orbital flight, while the changes in physiological parameters were reversible.

The paper of I. A. Skiba, I. K. Tarasov and V. V. Kalinichenko dealt with problems of biomedical preparation (BMP) for spaceflights.

The very concept of biomedical preparation of cosmonauts has evolved in the short history of manned cosmonautics from a "process that enhances man's resistance to spaceflight factors" (Mey M. Link, N. N. Gurovskiy, 1975) to a "system of measures that are interrelated in content and time of implementation, which provide for the readiness of cosmonauts to fulfill his program with respect to physical and psychological traits, knowledge, ability and skill in functioning during spaceflights." Thus, the evolution of the concept of BMP was due to the increasing complexity of spaceflight tasks: from survival in flight to capacity for complicated professional performance as a crew member (including extravehicular activity) in the course of long-term missions.

Thus, BMP comprises the following measures:

Screening candidates according to health status and psychological personality traits, dynamic observation during training.

Determination of baseline functional capacities of the body, the cosmonaut's personality, preparation of an individualized plan for health-improving measures and regimens for conditioning for spaceflight factors.

General and specialized physical training.

Specialized training for spaceflight factors.

Medical-psychological conditioning.

Training for medical part of the flight program.

Sanitary-hygienic and epidemic-control provisions.

Medical support of professional training on simulators and under difficult living conditions.

The BMP process is based on principles of improving adaptability, flexibility of the body and personality of the cosmonaut, unity and oppositeness of the adaptation process--readaptation in the spaceflight cycle, preadaptation to dynamic spaceflight factors, formation in the cosmonaut's consciousness of a conceptual model of the flight, along with other previously known methods of training and conditioning.

Implementation of this BMP system has improved substantially the professional efficiency of cosmonauts, which was instrumental in the general achievements of Soviet cosmonautics.

The more complicated flight programs, including increase in volume of extra-vehicular activity of crews, require further improvement of the effectiveness of BMP.

Subsection 1 "Physiological and Hygienic Problems of Manned Spaceflights and Flight Practice; Space Biology" (Directors: A. I. Grigoryev, I. D. Pestov and V. V. Kalinichenko; Scientific Secretaries: V. S. Kazeykin and G. S. Ratner)

Among the papers dealing with physiological problems, we must single out the one by F. A. Solodovnik, "Some Theoretical Aspects of Motion Sickness in Cosmonauts." Having summed up numerous studies, the speaker demonstrated that in weightlessness no increase is observed in sensitivity of vestibular system or its reactivity, and there are no pathological vestibular symptoms. All this is indicative of normal function of the vestibular analyzer under spaceflight conditions and absence of a link between development of motion sickness in cosmonauts and any functional vestibular disturbances whatsoever. It can be assumed that cosmonauts with distinctions referable to the function of the reticular-limbic complex that controls autonomic functions and adaptive reactions of the body are subject to motion sickness.

The paper of N. Ye. Panferova, V. M. Baranov, and V. I. Pervushin, "Evaluation of Human Tolerance to Graded Physical Loads," touched upon the question of selecting methods refined on earth that would be adequate for space studies. The results of investigations revealed the importance of selecting appropriate tests to study the mechanisms of the effect of weightlessness on cosmonaut tolerance to physiological loads. It was established, in particular, that conditioning on a bicycle ergometer leads to decrease in "physiological cost" of loads: pulse rate, energy expenditures, oxygen uptake and carbon dioxide output diminish.

A. D. Voskresenskiy demonstrated the feasibility of using methods of discriminant and factor analysis to elaborate criteria of the physiological norm and evaluate the status of cosmonauts. Finding the linear discriminant function made it

possible to distinguish between preflight and postflight reactions to the LBNP [lower body negative pressure] test and demonstrate intensification of reactions to LBNP during flights. The results of separate factor analysis of ground-based and flight data pertaining to cardiovascular reactions to LBNP revealed that the increase in circulation volume (CV) in flight, as compared to the preflight level, is associated with a more marked decrease in orthostatic stability and intensification of postflight response to LBNP.

Hypogravity changes in bones is still a serious problem of space biology and medicine. An interesting paper was delivered on this subject by G. P. Stupakov, V. S. Kazeykin, and A. I. Voloshin. The authors made a comparative physiological analysis and generalization of data concerning changes in the bone system of man and animals (rats, dogs, turtles) submitted to weightlessness or hypokinesia for different periods of time. It was concluded that there are differences in chatacteristics of osteodystrophic processes that develop at the relatively early and long-term stages of exposure to hypogravity. At the early stage of development, osteodystrophy is manifested by some decrease in calcium concentration in the organic component and decrease in bone strength without clearcut signs of loss of bone mass. Such changes can be attributed to transient decrease in strength of the collagen-crystal bond. At the later stage, there is loss of bone matter with dissociation of mineralization processes, as well as synthesis and resorption of bone.

Two papers were concerned with problems of assuring decompression safety of crews on the first day of flight and investigation of probability of altitude decompression disorders in simulated weightlessness (V. I. Chadov, A. S. Tsivilashvili, L. R. Iseyev and L. R. Iseyev, A. F. Zubarev, V. I. Chadov). The authors succeeded in establishing a relationship between minimal permissible working pressure in the spacesuit and duration of flushing nitrogen from the body in a hypobaric (550 mm Hg) normoxic atmosphere following a 2-h stage of saturation at a pressure of 840 mm Hg. It was also shown that use of the method of ultrasonic ranging of gas bubbles in the bloodstream is rather important and promising, since decompression air embolisms located by ultrasound appear in the blood of the pulmonary artery before the symptoms of altitude-decompression disorders, and they persist longer than other symptoms.

The paper delivered by A. A. Koreshkov et al., "Change in Carbon Dioxide Levels During Ordinary and Shifted Work and Rest Schedules (Sleeping-Waking Cycle) on the Salyut-7--Soyuz-T Orbital Complex," demonstrated the great practical value of identifying changes in carbon dioxide content in manned space vehicles for analysis of the level of cosmonauts' motor activity and evaluation of their tolerance to shifts in the daily cycle.

There was a wide spectrum of papers dealing with metabolism in real or simulated weightlessness (N. D. Radchenko, A. A. Drozhzhin, V. P. Matveyev, I. G. Popov and A. A. Latskevich; Ye. G. Vetrov; V. Ye. Potkin and I. O. Pakhlavuni; I. A. Popova et al.). Proper understanding of the role of amino acids, vitamins and enzymes in metabolism is still important to planning nutrition for cosmonauts during long-term spaceflights.

The paper delivered by V. F. Doroshev et al. dealt with the distinctions of changes in venous pressure during 120-day antiorthostatic [head-down tilt]

hypokinesia. It was shown that the dynamics of venous circulation had considerable individual variability; some parameters of venous pressure can be used to predict subjects' orthostatic stability.

The capabilities of ultrasonic vasography in the presence of long-term accelerations were discussed in the paper of V. A. Degtyarev, N. V. Soloshenko and M. N. Khomenko. They demonstrated the potential of using the method they developed for detection of early signs of changes in blood supply to the central nervous system.

The paper delivered by R. A. Vartbaronov et al., which dealt with determination of the proportion of long-term adaptive and cumulative effects of regular exposure to maximum tolerated accelerations, revealed functional changes in the animal cardiovascular and respiratory systems; they developed a set of informative criteria that are needed to monitor the functional state.

V. V. Yasnetsov and V. S. Shashkov tried to determine in their investigation the role of endogenous morphine-like agents in the pathogenesis of motion sickness. Their data have helped gain a fuller idea about the mechanism of development of motion sickness and delineate new directions for preventing it.

Biomechanical validation of the means of optimizing the man-ejection seat system with exposure to impact accelerations was the subject of the paper of G. P. Stupakov et al. Using an original method to measure deformation of the vertebral bodies, they made a quantitative determination of the influence of initial body position, immobilization of shoulder belt, liners that "profile" lumbar lordosis on tolerance to impact accelerations.

A team of authors (V. I. Korolkov, M. A. Dotsenko, A. N. Truzhennikov and others) investigated simian adaptive reactions to impact and vibration accelerations. The findings made it possible to have a susccessful flight with animals in Cosmos-1514 biosatellite.

In their paper, A. P. Kozlovskiy et al. demonstrated the main directions of optimization of gear to protect the pilot's upper extremities against air flow. Determination was made of permissible mechanical loads leading to removal of hands from ejection controls.

V. Ye. Potkin, V. I. Plakhotnyuk and A. G. Gavrilenko defined the criteria for assessing lipid metabolism in flight personnel on the basis of the results of integrated investigations.

Several papers dealt with physiological and hygienic problems of manned spaceflights. T. P. Tikhonova reported on a new methodological approach to validation of maximum permissible level of one-time exposure to an environmental factor that is deleterious to man. The method is based on determining the probability of onset of specific changes with a minimized number of experiments.

V. I. Belkin et al. reported on evaluation of air pollution in closed environments by the products of combustion of nitrogen-containing polymers.

The paper of K. D. Rokhlenko et al. contained information about dust in the gas environment of closed environments, sources of dust particles and need to institute measures to reduce this factor.

The paper by V. I. Korolkov et al. reflected data on parameters of the gas environment and microclimate, sanitary and hygienic living conditions for animals aboard Cosmos-1514 biosatellite. Several refinements made it possible to improve the above parameters.

Two papers dealt with embryonic development of amphibians (E. A. Oygenblik) and fish (Ye. M. Cherdantseva) in weightlessness and hypergravity. The findings made it possible to understand better the changes that occur in living organisms in the presence of certain changes in gravity.

Some interesting data concerning development of plants in weightlessness were submitted by M. G. Tairbekov.

The last paper in this cycle dealing with biology was an interesting one by L. L. Zhurni, "Conception of Scalarity and Forecasting Long-Term Biological Effects of Weightlessness."

In summing up the work of this subsection, I. D. Pestov and A. I. Grigoryev remarked that most of the papers delivered served as the subject of discussions that were deployed during the meetings. It was proposed that the work of the subsection during the next Gagarin lextures be concentrated on one or two of the most important current problems, in particular, space motion sickness.

Subsection 2 "Patterns of Correlation Between Mental and Physiological Processes During Flight Work" (Directors: P. V. Simonov, G. M. Zarakovskiy, O. I. Zhdanov; Scientific Secretaries: V. A. Kurashvili, S. L. Rysakova)

A total of 18 papers were delivered and discussed at the meeting of the subsection. They were all concerned with validation of the means of improving efficiency and preserving the health of pilots, cosmonauts and specialists in flight control systems. These routes and the corresponding directions of investigation are rather diverse. Some of them were discussed at the meeting.

The first of these directions is purposeful organization of work. A. V. Smetanin and V. F. Nesterov demonstrated that optimum grouping of tasks performed by cosmonauts and alternation of psychophysiologically different types of work operations increase appreciably labor productivity during spaceflights. It is necessary (paper by V. I. Makarov and L. R. Pravdina) to monitor the mental state of cosmonauts by methods of expert evaluations by neuropsychiatrists at the mission control center. An interesting fact was discovered: shifting work and rest schedules have a stimulating effect. This effect may be related to emotional animation in view of the changes made in the monotonous conditions of long-term flights. V. I. Myasnikov, B. N. Ryzhov and I. R. Abramov proposed some integral normalized parameters (with possible values of 0 to 1) of quality of performance, level of psychophysiological tension and an overall indicator of efficiency of performance (derived from the first two), in order to improve the objectivity of evaluating functional states during forced wakefulness. It was shown that there is a quantitative correlation between increase in quality of performance and its psychophysiological cost when there is increased motivation. G. M. Zarakovskiy and V. I. Savchenko disclosed the psychophysiological essence of mobilizing the body's resources under the influence of different types of motives and forces. On the basis of the results of

an investigation, it was shown that the specific outlay of psychophysiological resources per unit increment in performance quality is lower in the case of motivation to achieve success than motivation of avoidance of failure.

An interesting idea for enhancing the reliability of operator performance was validated by L. G. Dikaya. It is desirable to form the functional subsystem of physiological implementation of the process of reaching the goal when working under special conditions concurrently with formation of skills and habits, i.e., in the presence of different functional states. This is associated with appearance of specific "activation patterns." New data concerning the fluctuating nature of nonspecific activation of performance and role of periodic processes in the structure of functional states were submitted by V. A. Salamatov.

The productivity of ideas that ensue from combined analysis of mechanisms of physiological and mental processes was brilliantly demonstrated in papers dealing with pharmacological agents for controlling man's work capacity. S. I. Sytnik and L. K. Pashuk proposed that the peripheral components of functional structure of generation of emotional reactions be the target. As a result, it was possible to find adrenoblocking agents that normalize emotional stres. V. M. Kalosha, N. A. Davydova, I. B. Goncharov and L. G. Polevoy demonstrated an adaptive effect in psychotropic (nootropic) agents and showed how they could be used to enhance the efficiency of flight work.

Several papers were concerned with different specific aspects of optimization of flight work. Thus, A. A. Medenkov and S. L. Rysakova analyzed errors in verbal exchanges between controllers and aircraft crews, and they offered a number of recommendations. V. D. Vasyuta validated the characteristics of seats (molded back, air pillow, etc.) that retard the fatigue process.

I. F. Chekirda, A. A. Malofeyev, as well as A. K. Yepishkin, Ye. A. Ivanov and L. S. Khachaturyants, submitted data on the structure of movements and improvement of sensorimotor tracking during spaceflights. Data referable to studies of higher nervous activity in monkeys, which seemingly had no direct bearing on the problem of psychophysiological bases of efficient flying, turned out to be quite interesting. In their paper, G. G. Shlyk et al. submitted data on the correlation between the distinctions of simian higher nervous activity and adaptation to spaceflight conditions. These data revealed, in particular, that the psychophysiological characteristics that determine the place of an individual in a group, his social behavior, play a large part.

V. G. Voloshin et al. proposed some new psychophysiological methods that improve the reliability of forecasting the potential of aviation-related athlete-operators. S. V. Panferov and T. I. Milyavskaya submitted the results of a study of parameters of binocular vision in civil aviation pilots.

A paper on formation of knowledge and skill in aviation physicians through postgraduate training (N. A. Razsolov, K. A. Pimenov, V. N. Razsudov, V. D. Yustova) seemed to summarize the means of adopting all of the submitted recommendations in the practice of medical support of flights.

Subsection 3 "Problems of Space and Aviation Psychology" (Directors: G. T. Beregovoy, V. A. Ponomarenko; Scientific Secretary: N. V. Krylova)

A total of 67 papers and reports were delivered and discussed, and they dealt with these scientific directions: theoretical and methodological problems of space and aviation psychology; psychological aspects of training and performance of operators; clinical psychological problems of level of training of air and space crews.

The results of theoretical and experimental studies of spatial orientation in flight were submitted in several papers (V. A. Ponomarenko et al., N. A. Nosov, Yu. P. Shipkov, A. G. Fedoruk and others).

As a development of the theoretical thesis advanced by N. D. Zavalova concerning spatial orientation as an independent action, a study was conducted in order to define the role of activity of interaction between the conscious component of the standard pattern and acceleration signals contained in the flow of feedback from performance of controlling actions. It was shown that acceleration signals in themselves and the primary receptor field do not rule out afferentational impulsation, while the significant mismatch between a given position in the standard pattern and current position causes better sensory correction. New directions of formation of human resistance to spatial illusions may be an important consequence of that established fact.

Difficulties in spatial orientation are one of the causes of diminished quality of flight personnel performance of their professional work. The capacity for spatial orientation depends largely on the individual profile and degree of asymmetry of cerebral hemispheres, arms and vision. Data on extent of functional asymmetry can be used in screening operators for dynamic systems and predicting their functional reliability.

It must be stressed that the "gravity picture of a flight" is directly related to means of orientation, and this must be borne in mind when solving problems of displaying the spatial position of an aircraft.

A large group of papers was concerned with investigation of different aspects of operator work.

V. A. Perov et al. discussed questions of sensorimotor coordination. In accordance with the structural and functional approach as the methodological basis of investigation, it was shown that sensorimotor coordination is a case of cognitive and regulatory matching on the lower (sensory) level of mental reflection. The results of experiments led to the conclusion that parameters of sensorimotor coordination of pilots and cosmonauts carry a large professional load, and they made it possible to define a general mathematical model of operator work.

Combined psychophysiological characteristics and their potential with respect to forecasting and evaluating the effectiveness of operator performance were discussed in the paper of F. B. Berezin. It was shown that the combined characteristics obtained differ in composition of importance of elements they contain, depending on criterion of achievement used to separate the standard groups.

Use of the systems approach to psychological evaluation of information display equipment (IDE) made it possible to formulate the main guidelines specifying its methodology: principle of conformity of IDE to content of the pilot's tasks; principle of preservation of reliability of perception and processing of information displayed on new IDE in changing environmental conditions; principle of reliability of pilot actions with change in his functional state and evaluation of new IDE. Multilevel investigations of new IDE elicited the causes and mechanisms of pilot problems with use of such equipment and validated specifications to optimize the psychological characteristics of IDE (V. A. Ponomarenko et al.).

L. N. Popov et al. submitted a complex for the study of operator performance, which includes a microcomputer that permits automation of processes of formation of information support of pilot work, recording parameters and characteristics of his psychophysiological state, as well as ongoing data processing.

A. S. Zharov made a study of quantization of operator controlling movements on the basis of a general mathematical model of operator work. Questions of formalization of the input information model describing the performance of a well-trained operator are discussed on the basis of the principle of "minimal subjective complexity" (N. G. Rylskiy).

The choice of means of delivering visual stimuli in tasks of multicircuit and multiparameter control was discussed by A. V. Yefimov. It was shown that operator performance of a tracking task in several circuits is an effective means that provides for the best variant of a visual display.

A study of perception of digital information under conditions of programmable self-regulation (S. F. Sergeyev) revealed that it is possible to control the speed of visual perception.

Some of the distinctions of operator performance when exposed to parameters of the environment related to his individual personality traits were covered in the papers of V. Ye. Yastrebova and S. M. Razinkina, T. V. Isayeva and A. A. Bezbogov.

Several papers dealt with questions of correction and evaluation of psychophysiological state in the general methodological and specific applied aspects.

V. I. Ilyin relates personality set to individual correction of a state, stressing the importance of developing criteria that would permit scientific validation of individualized choice of correction methods. A special set of autogenic training exercises was included in an anechoic chamber experiment, with simulation of operator work of cosmonauts in systems of control, communication and visual observation, in the presence of the main spaceflight factors (L. P. Grimak, A. K. Yepishkin). The beneficial effect of such training was reported, which can be attributed to both its elimination of adverse psychophysiological reactions to simulated working activity and activation of the body's adaptation reserves.

The feasibility of assessing a pilot's condition in unique flying conditions is extremely important and pressing. This is a difficult task, since there

are no regular systems at the present time for monitoring the pilot's inflight functional condition.

The paper by I. M. Alpatov et al. proposed an approach to expert psychophysiological evaluation of the pilot's state under unique flying conditions, using such parameters as the pilot's health status, psychological criteria of his personality, adequacy of his behavior and actions in emergency situations. Determination is made, on the basis of considering all of the obtained information, of the consistency of demonstrated deviations with the inflight functional changes. A comprehensive examination of the data permits more reliable evaluation of the pilot's condition under extreme flying conditions.

L. P. Grimak and V. M. Zvonnikov discussed the psychotherapeutic aspects of prevention and restoration of functional disturbances among flight personnel, and they propose the use of different modifications of autogenous training, as well as methods of optimum psychotherapy and hypnosis, for these purposes.

V. A. Bodrov and V. V. Kharin conducted investigations of the feasibility of using a flight simulator as an occupational load test for rehabilitation of pilots with functional disturbances of the nervous and cardiovascular systems. The method is based on reproducing on the simulator the elements of an instrument flight and its typical complications. The capabilities and efficacy of this method were demonstrated.

Successful pilot performance is directly related to his having good flying skills, which are demonstrable through professional screening. For this reason, it is important to refine the system and methods of vocational screening.

Ye. D. Sokolova and A. Ch. Agayev showed the prognositc value of examining mental adaptation of flying school cadets, which is done using a set of psychodiagnostic methods.

V. M. Zvonnikov and B. L. Pokrovskiy discussed the possibility of improving professional pilot screening and propose a basically new approach to it, which is on the boundary between medicine and psychology. Its main element is the search for methods that define the biological bases of professionally important mental traits and adaptive reserves of the body.

The results of professional screening in the course of flight work are periodically checked by the commission for expert medical certification of pilots (VLEK). Several papers (G. S. Mazanov, V. F. Volokhov, V. I. Bysikov, I. M. Pimenov) described the guidelines for expert clinical and psychological evaluation of flight personnel under the conditions prevailing at a permanent VLEK, and discussed the content of psychological conclusions referable to individuals seen by the VLEK.

There was a group of papers dealing with different elements of operator work and improvement of teaching methods.

S. V. Yegorov et al. investigated the effect of visual sensory monotony on mental processes on different levels. It was established that actions, the

control of which is effected on the perception level, are the least resistant to monotony. It was shown that it is imperative to call the operator's attention to current instrument readings by means of performance of additional tasks included in the structure of his professional work.

A. Ya. Abrazhevich et al. investigated the dynamics of change in strategy of information search in an observer-operator. They determined the patterns of change in time and precision parameters of operator work, with consideration of the influence of spatial uncertainty, various levels of effects of interference, individual psychological traits and functional states of operators, etc. There was validation of methodological guidelines for optimizing information search under different conditions of uncertainty of operator work.

V. V. Chumakov and A. N. Razumov discussed in their paper the question of optimizing interaction between an operator and multimodal information systems. A procedure was used to create special situations that require active, purposeful actions on the part of the operator in order to eliminate them. Analysis of experimental data revealed that a combination of lights on a visual indicator of an informative report with concurrent repetition and issuance of recommendations by the verbal announcement equipment is the optimum.

The distinctions of imaged activity of an operator controlling a dynamic object as related to automation are discussed in the paper of V. V. Lapa and V. V. Polyakov. It was established that during short-term (15-20 min) control in automatic mode favorable conditions are generated for formation of the mental image of a flight, which permits validation of the use of this mode as the basic one for brief control of a dynamic object under difficult conditions.

I. B. Solovyeva showed that training for actions in particularly difficult (irregular) flights using simulators must be supplemented with special psychological training aimed at formation of professionally important skills and capacities in the cosmonaut, which are needed to assure efficient performance under complicated flying conditions.

There was a large group of papers concerned with development of methods of psychological examination in cosmonautics and aviation.

O. I. Zhdanov believes that noninstrument methods, such as observation and conversations are the most practical for the study of psychological aspects of operator work in a special field. A. V. Nikonov and L. V. Inozemtseva propose acoustic methods of psychodiagnosis according to speech characteristics to assess the functional state of operators, while V. N. Trofimov and V. F. Shevchenko use the change in characteristics of heart rate as a universal indicator, in order to determine operator resistance to spaceflight factors.

Questions of correlation between objective and subjective methods of psychodiagnosis of functional states of man were discussed in the paper of A. B. Leonova. She stressed the self-contained role of subjective data in the psychodiagnostic process. It was shown that the success of using methods of either class is determined by their adequacy for concrete diagnostic problems.

V. I. Pokhilko discussed psychometrics of individual differences in the interests of individual-oriented psychodiagnostics.

The methods of evaluating operator compatibility, which are based on testing operator state in nonverbal interaction and were proposed by I. V. Smirnov and N. V. Gavrilova, are specially designed for cases of long-term joint interaction of operators in isolated systems.

G. L. Strongin and S. B. Shesterneva investigated the sociopsychological climate among civili aviation crews, as a result of which they formulated recommendations on manning flight crews in order to create and maintain a favorable psychological climate.

L. P. Grimak developed auto-ophthalmotraining (AOT), which is based on assimilated skills from a course of autogenic training, in order to enhance visual work capacity of operators. The AOT method was checked in the course of 48 h of continuous work, and its efficacy was confirmed.

Several of the papers delivered were concerned with special aspects of interest to aviation and space psychology.

L. G. Yeliseyeva discussed questions of esthetic design of cosmonauts' work clothes from the standpoint of psychophysiological comfort. It was shown that the distinctive features of work clothes affect the emotional background of an individual, and this acquires special meaning in the case of long-term spaceflights. Sketches of work and flight clothes for cosmonauts were submitted, in the development of which psychological and psychophysiological recommendations were taken into consideration.

I. S. Zamaletdinov et al. investigated the compatibility of air traffic controllers and radio operators who communicate with pilots and cosmonauts according to psychophysological parameters of thinking in words. Concrete methods were proposed for screening and special training of air traffic controllers and operators pertaining to synchronized communication in the radio communication system.

Data on the effects of long-term sleep deprivation of human adjustment to altered work and rest schedule were reported by A. N. Litsov. The changes demonstrated in the course of his study in the parameters reflect the degree of resistance of the human central nervous system to prolonged sleep deprivation, as well as distinctions in function of the body's circadian system.

In his paper, R. B. Bogdashevskiy expounded the thesis of several categories of mentality and their interaction, with consideration of the additiveness principle. He formulated the principle of controllable information and ecological personality relations, which consists of retaining and developing the individual life style.

D. V. Gander described the essence, content and tasks of the psychological service in the Air Force, and singled out the classes of tasks for the aviation psychological service.

The paper of B. M. Galeyev about music programs for adaptation to weightlessness was accompanied by a screening of films that illustrated the hypothesis of associative reception of gravity in music.

The data submitted at subsection meetings enable us to gain an idea about both the problem as a whole and concrete special problems of aviation and space psychology. We must mention some of the positive factors: involvement of psychologists in the work of VLEK, expansion of work on psychology and psychological climate, paying attention to subjective methods of evaluation. Several papers expounded new and interesting theses concerning spatial orientation illusions, the link between personality tests and behavior in emergencies as related to information received, and about the rehabilitation system.

As was the case at prior lecture series, there were 10 sections and Gagarin lectures for students. The distinctive feature was a joint "round-table" meeting of four sections, which dealt with the problem of "Man and Automated Systems in Cosmonautics and Aviation." This meeting was chaired by N. N. Rukavishnikov, and N. V. Krylova was the scientific secretary.

At this meeting, which included active and interesting discussions, several issues were discussed that had a direct bearing on problems of medicine, physiology and psychology. In their speeches, B. F. Lomov, A. N. Lebedev, G. M. Zarakovskiy and V. A. Ponomarenko demonstrated, using concrete examples, the need for optimum utilization of data about human psychological and physiological characteristics for development of automation equipment, including so-called "intellectual programs." Guidelines were formulated for the optimum interaction between pilots, cosmonauts and operators, on the one hand, and automated machines, on the other, when solving various inflight problems. It should be noted that, in spite of a number of debatable questions, most of the representatives of engineering sciences and practice (N. N. Rukavishnikov, A. A. Krasovskiy, V. V. Malozemov and others) who participated in the discussion were also against excessive enthusiasm for automation that excludes man from the control circuit. It was noted that it is imperative to submit all concrete questions of automation in aviation and cosmonauts to thorough critical analysis, not only from the engineering point of view, but also the psychophysiological one.

ANNIVERSARY

UDC: 612.85+616.28-092].92 Markaryan

SUREK SEROPOVICH MARKARYAN (70TH BIRTHDAY)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (signed to press 19 Jun 86) pp 95-96

[Article by editorial board]

[Text] The 3d of August 1985 marked the 70th birthday and 44th year of medical, scientific and public work of Professor Surek Seropovich Markaryan, doctor of medical sciences and retired colonel of the medical service.

S. S. Markaryan was born in 1915 in Rostov-on-Don. Upon graduating from the Second Moscow Medical Institute imeni N. I. Pirogov in 1941, he was called up into the Red Army. Surek Seropovich traveled a difficult road from battalion physician to chief of an evacuation hospital in the years of the Great Patriotic War. He was a participant in the defense of Moscow, and has been a member of the CPSU since 1945.

Having spent 1946-1949 at the Moscow Scientific Research Institute of Ear, Nose and Throat, RSFSR Ministry of Health, for his clinical residency, S. S. Markaryan worked enthusiastically in scientific research at the same institute. His first scientific publication was the article "Question of Symptomatology and Therapy of Acute Otitis Associated With Dysentery in Infants."

In 1954, S. S. defended his candidatorial dissertation and in 1969, his doctoral one. In the latter, he summed up extensive experimental material and provided theoretical validation and practical recommendations on methods of vestibular screening.

His good theoretical training, great knowhow in reserach work, mastery of a broad armamentarium of methodological investigative procedures and ability to determine the most important direction for solving scientific problems enabled S. S. Markaryan to conduct several studies on pressing problems in the area of physiology and pathophysiology of ENT organs, problems that were important to theory and practice of aerospace and naval medicine.

The main investigations of S. S. Markaryan dealt with interaction between the acoustic, vestibular, visual and tactile analyzers under extreme conditions and determination of maximum velocities of rotations in different planes for man and animals.

The studies of S. S. Markaryan of vestibular and auditory analyzers during exposure to noise and vibration in aviation are of great practical interest. He established that these factors can elicit persistent functional changes in these analyzers. His findings served as the basis for defining permissible levels of noise and vibration.

The work of S. S. Markaryan on finding the mechanisms of motion sickness is of particular theoretical and practical interest.

A new method of evaluating and predicting individual vestibular stability of candidates, pilots and cosmonauts was developed and adopted in expert medical certification of flight personnel under the supervision of S. S. Markaryan and with his direct involvement. He made a sizable contribution to development and design of an entire series of vestibulometric chairs and stands with a wide range of angular, linear and Coriolis accelerations. This work resulted in 6 inventions and 17 innovative proposals, which have gained wide practical use in solving scientific research problems of aerospace medicine.

For his participation in development of new medical equipment, the gold and two bronze medals of the Exhibition of Achievements of the National Economy of the USSR were conferred upon S. S. Markaryan.

S. S. Markaryan has authored more than 130 scientific works, including monographs and a number of methodological aids for practicing physicians.

S. S. Markaryan devoted much attention to education and training of scientific personnel. Seven candidatorial dissertations were prepared and successfully defended under his guidance.

In recent years, the scientific endeavors of S. S. Markaryan have been closely linked with the demands of practical health care. The influence of the noise and vibration factor on man on shipboard is being investigated under his supervision. The results of these studies have been reflected in the standard-setting documents of the USSR Ministry of Health and GOST [All-Union State Standard].

S. S. Markaryan is very involved in public service, being a member of the commission for introduction of new instruments and equipment to otorhinolaryngology under the USSR Ministry of Health, member of the Scientific Council of NIIGVT [Scientific Research Institute of Water Transport Hygiene] of the USSR Ministry of Health, and preceptor of the council for young scientists and specialists.

S. S. Markaryan has transmitted his enthusiasm for work to his disciples. He enjoys deserved authority among his coworkers and the scientific community.

State awards have marked the endeavors of S. S. Markaryan.

His fellow workers and friends sincerely congratulate Surek Seropovich Markaryan on his 70th birthday, wishing him good health and further success in his work for the good of our homeland.

OBITUARY

UDC: 613.693.:92 Parfenov

GLEB PETROVICH PARFENOV

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 20, No 4, Jul-Aug 86 (signed to press 19 Jun 86) p 96

[Article by editorial board]

[Text] Gleb Petrovich Parfenov, doctor of biological sciences and laboratory chief at the Institute of Biomedical Problems, USSR Ministry of Health, died suddenly on 17 June 1985, in his 54th year.

The life of an outstanding scientist and remarkable person, whose work in the area of space biology and, in particular, space genetics, is well-known both in our country and abroad, came to an untimely end.

Gleb Petrovich Parfenov was born on 2 October 1931. After graduating from the medical department of Moscow State University imeni M. V. Lomonosov, he worked in the laboratory headed by Academician N. P. Dubinin.

The endeavors of G. P. Parfenov were linked with space biology from 1960 to the time of his death. He stood at the threshold of the birth and development of this branch of science.

G. P. Parfenov made a substantial contribution to the study of the effects of spaceflight and space factors on the genetic structures of living organisms. The experimental data obtained by Gleb Petrovich and his colleagues aboard the first artificial satellites of earth, along with other data, made it possible to validate the safety of manned flights in near space.

G. P. Parfenov devoted much attention to investigation of the effects of weightlessness on basic biological processes. Unique experiments on various types of space vehicles, Cosmos biosatellites and manned spacecraft were conducted by the laboratory staff under his guidance.

G. P. Parfenov made an inestimable contribution to development of theory of gravity biology. His fundamental book, "Weightlessness and Elementary Biological Processes," is an outstanding monograph and, at the same time, an educational aid.

G. P. Parfenov was always involved in scientific research, successfully developing the ideas of N. V. Timofeyev-Resovskiy and O. G. Gazenko concerning the

need to investigate microevolution, problems of genetic homeostasis of populations in order to reach a number of practical purposes of cosmonautics.

G. P. Parfenov, who has authored about 100 scientific publications and numerous papers for symposiums, congresses and meetings, devoted much effort to the training of scientific personnel, work on different councils and commissions dealing with problems of space biology and medicine at the USSR Academy of Sciences and USSR Ministry of Health.

A bright memory of Gleb Petrovich Parfenov will always remain in the hearts of his coworkers and friends.

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